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ADVENTURING IN SCIENCE

By

SAMUEL RALPH POWERS
Professor of Natural Sciences
Teachers College, Columbia University

ELSIE FLINT NEUNER
Director of Instruction
New Rochelle, New York

HERBERT BASCOM BRUNER
Professor of Education
Teachers College, Columbia University

and

JOHN HODGDON BRADLEY
Author of *Parade of the Living,*
Autobiography of Earth,
Patterns of Survival

SUMMER SCHOOL FOR TEACHERS

Using Our World

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ADVENTURING IN SCIENCE

EXPLORING OUR WORLD

OUR WORLD CHANGES

USING OUR WORLD

THE WORKBOOKS

DIRECTED ACTIVITIES I
EXPLORING OUR WORLD

DIRECTED ACTIVITIES II
OUR WORLD CHANGES

DIRECTED ACTIVITIES III
USING OUR WORLD

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USING OUR WORLD

Eisenstaedt-Pix

USING OUR WORLD

If our Stone Age ancestors could rise from their graves, they would see sights and hear sounds that might well frighten them back to their graves. The spectacle of modern life would burst on them without warning: mighty buildings reaching toward the sky, trains and automobiles racing over the land, voices mysteriously traveling through empty space. How terrifying all this might be to men who never even dreamed that such wonders could exist!

◆

We moderns, on the other hand, take the spectacle for granted. It does not frighten us at all; in some cases it does not even interest us. We are likely to forget that the ordinary things and events of today were the mysteries and miracles of yesterday. We are likely to forget that much of what we take as a matter of course is the result of man's unceasing curiosity to know about the earth on which he lives, and his endless struggle to make it serve his needs.

◆

In this book we shall study the results of that curiosity and struggle. We shall study the things which we ordinarily take for granted. In doing so we should gain much useful knowledge. We should also gain some sense of the wonder of the world and the adventure of human achievement.

UNIT ONE

THE LIVING RESOURCES OF EARTH

THE LIVING RESOURCES OF EARTH

Where shall we begin to study a world so full of so many things? Might we not best begin where our life itself begins, with the plants and animals that feed and clothe our bodies? Man is deeply interested in his neighbors of the living world because without them he could not exist. He has always striven to make these neighbors serve him.

* * *

He has striven to improve the crude wild plants of the primitive earth because plants are his chief defense against the ever-present menace of starvation. He has striven to domesticate the wild animals of field and wood, to enlarge not only his sources of food but also his sources of clothing and power. Man's progress in these endeavors is one of the most important chapters in the history of civilization. Let us see in this first unit of our study what that progress was and is.

CHAPTER ONE

How Do We Make Use of Plants?

THE EARLY CULTIVATION OF PLANTS

How Our Ancestors Got Their Dinner. Have you ever been really hungry for an entire day? If you are a typical American you probably have not. To be sure, you may have missed a meal or two for one reason or another. You may have wished that the spinach you were eating were corn on the cob, or the bread pudding were berry pie. But usually you have probably had enough to eat in sufficient variety to please your taste and promote your health.

Perhaps you do not realize how fortunate you have been. Men have not always been so fortunate. Our early ancestors were not strangers to hunger and even starvation when game grew scarce or crops failed. Even when blessed with a surplus of food, men have not always been able to preserve it for future need. Nor have they always been able to carry food from regions of plenty to regions of famine. Rapid transportation, artificial heating, and artificial refrigeration, which make this possible, are all modern inventions.

Our earliest ancestors probably wandered from place to place, taking what food they could find. They depended chiefly on the wild animals of the forest and the fish of lake and sea. They ate such seeds, leaves, roots, and berries as tasted good to them. Sometimes they feasted and sometimes they fasted, depending on the luck of the moment.

When men learned to cultivate food plants and to domesticate wild animals, they made two of the greatest advances in human history. By this means only could a

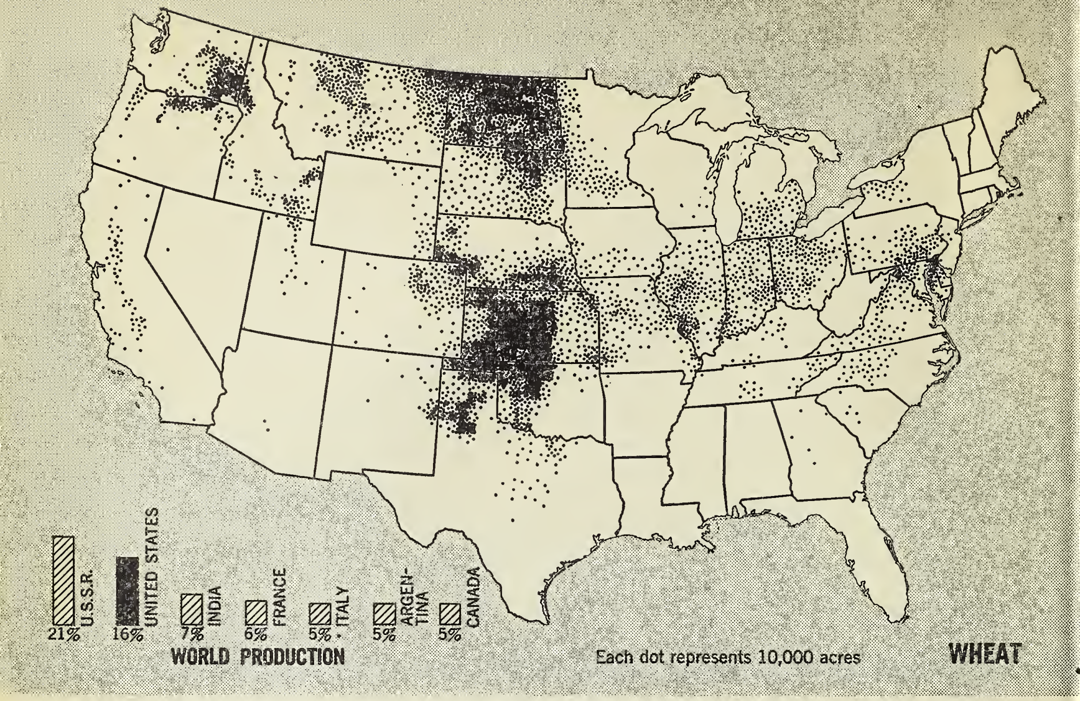
Sawders

Here are a few of the millions of American acres which are devoted to the cultivation of wheat

dependable food supply be established and the threat of famine removed. And only by this means could men settle down in one spot long enough to learn the arts of civilization.

The Importance of Farming. The history of civilization is in no small measure the story of man's career as a farmer. Though some of our common food plants have been cultivated for thousands of years, much progress in the growing of these plants has been made in that time. Men have forever striven to improve their farm lands and to improve and increase their crops. How have they done this, and how do they continue to do this? Let us see.

Exercise. Try to imagine what you would eat if you were an Indian living in the place where you are living now, but three hundred years ago. What food would you have in



This map shows what the United States has achieved in the production of wheat

greatest abundance during May? during August? during November? during February? List meats, including fish and fowl; seeds, including nuts and grains; green and dried vegetables. How much of your food is wild, how much domesticated? How does this compare with your actual diet today?

Wheat, the "Staff of Life." Bread made from wheat has been called the staff of life because men in many lands have used it as food for many centuries. When was wheat discovered? Nobody knows the exact answer to that question. Students of history know that wheat was used for food by the lake dwellers of Switzerland some 10,000 years ago, and also by the ancient Egyptians. They believe that the cultivation of this grain probably spread from the region round Palestine into other parts of Asia, as well as into Africa and Europe.

The illustration below shows a stalk of the wild wheat which still grows in the neighborhood of Palestine. Beside it is a stalk of one of the best-yielding modern varieties. Between the two are centuries of study and experimentation by men in many countries. Today there are many varieties of wheat, some of them adapted to the harsh conditions of dry and cold lands, all richer in food-bearing seeds than the little wild grass plant from which they were developed. The map on the opposite page shows what Americans have done with the descendants of this plant.

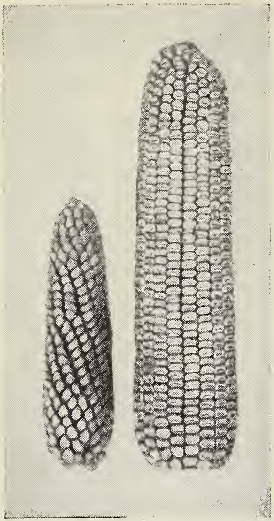
The wild wheat plant on the right is the distant ancestor of the modern wheat plant on the left

Corn. In England the seeds of wheat, barley, rye, and oats are all known as corn. In America we restrict the term to Indian corn, or maize. This familiar food plant is strictly a product of America. Though grown by early American Indians over wide areas, it was unknown in Europe until taken there by English and Spanish explorers. Originally a semitropical plant, maize was cultivated by the Indians as far north as the dry, sandy uplands of New York state, and as far south as the hot, damp lowlands of Central America and the hot, dry uplands of Peru.

How, you may ask, could the same type of plant be adapted to so many different conditions? The answer is that for each different condition the Indians developed a different variety of maize. To what extent the Indians intended to develop these different varieties, we do not know.

It is probable that new kinds of maize just naturally cropped up. Most likely, however, the more intelligent Indians were quick to take advantage of nature by selecting and planting the seeds of the best new varieties.

Like modern wheat, modern corn shows vast improvement over ancient varieties, as you can see in the photograph at the left. Corn crops cover more ground at present than any other crop in America. Three fourths of it goes to pigs, cattle, horses, and poultry. We consume the rest ourselves, in the form of corn, corn oil, corn sirup, and cornstarch. America, the home of the corn plant, is still the leading producer of corn, as the map on page 11 will show.

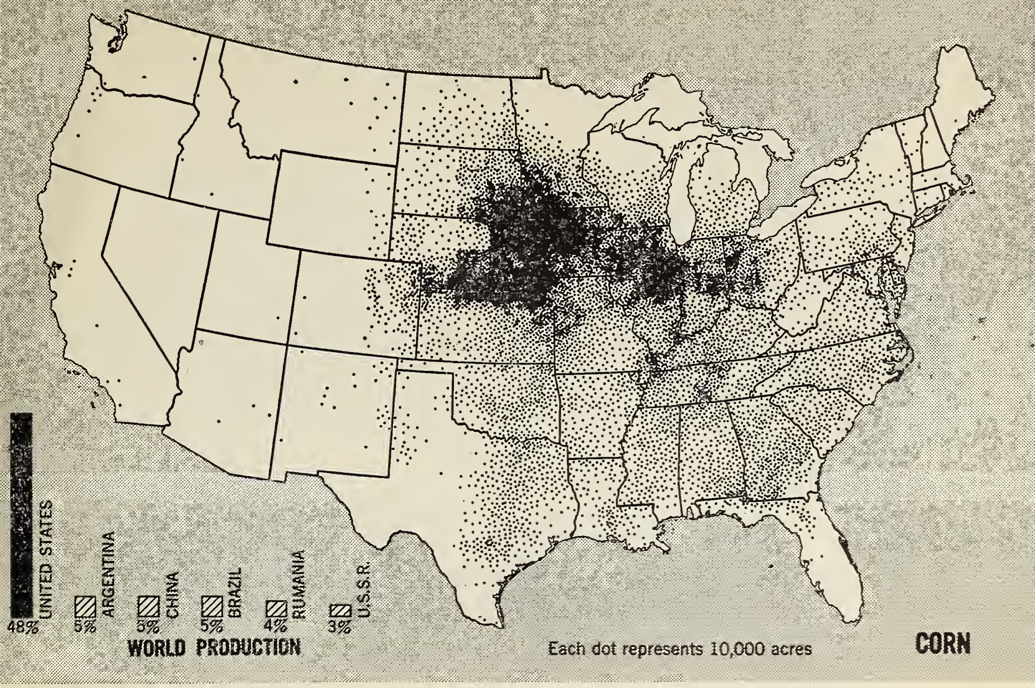


Harvard University

Corn, like wheat, has improved through intelligent cultivation

Exercises. Barley, oats, rye, rice, and millet are other grains which have been used by man and his domesticated animals for thousands of years. Look up recent figures on the production of these grains and also on the production of wheat and corn. You can find this information in the *World Almanac* or the *Statistical Abstract of the United States*. Which grain is the most abundantly produced in this country? in the world? Which the least abundantly produced? What should you say are the reasons for the differences?

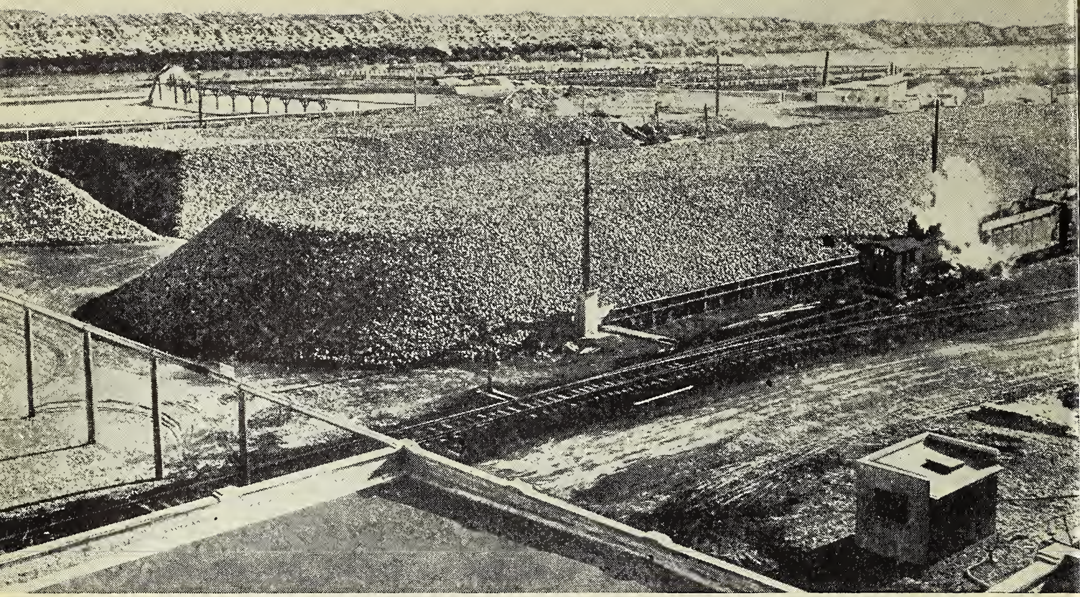
Today, some seven hundred million people live chiefly on rice. Look up and report on the history of rice as a food plant. Make a special study of Java, where the culture of rice is most highly developed.



This map shows what the United States has achieved in the production of corn

Sugar. Sugar cane, like wheat and corn, is a plant with a long history. It was grown in ancient India. The early Romans, Greeks, Egyptians, and Babylonians, on the other hand, had no sugars except honey and fruit juices. Sugar cane, indeed, was unknown in Europe until the Arabs introduced it from India in the Middle Ages. Used first as a medicine, it later came into more common use as a luxury for the rich.

With the opening of the New World sugar cane was brought into the West Indies, where it proved especially well adapted to the new soil and climate. In time it was raised there in larger and larger quantities, until rich and poor alike could have all the sugar they desired. Sugar-eating and civilization advanced together over the continent to the north. During the last century the yearly amount of sugar used in the United States has increased more than



U. S. Beet Sugar Association

These great piles of beets in an Oregon town will help to satisfy your craving for sugar

ten times. The people of the United States are now much the greatest sugar-eaters on earth.

Sugar cane is a tropical plant and grows successfully only in a very warm climate. It must have a long growing season; a good, rich, loamy soil; plenty of moisture and good drainage. In cooler climates, where sugar cane cannot grow, there is today a big industry in sugar beets. This industry began in 1747, when a German chemist discovered that beets contain exactly the same kind of sugar as that which develops in the pulpy stems of the sugar-cane plant. Though the production of beet sugar has increased since then, there is still about twice as much cane sugar as beet sugar produced in the world today.

Exercise. Why do you suppose more cane sugar is produced than beet sugar?

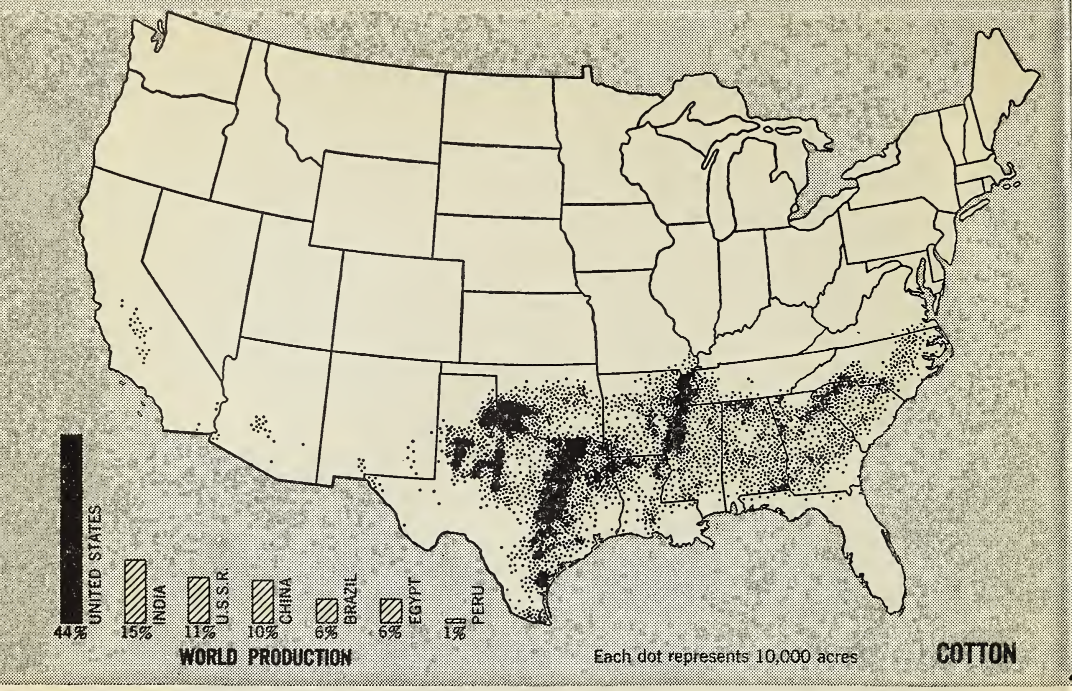
Cotton. Not all ancient cultivated plants were raised for food. Man has long gone to the plant world for clothing as well as for food, and cotton has long been a popular source of cloth. Like sugar cane, cotton was grown in India centuries before the Christian Era. Arabs brought it into Spain in the Middle Ages, but for a long time it was little used in Europe because cloth which was woven from the linen fibers of the flax plant was cheaper.

When Columbus discovered America he found the natives of the West Indies dressed in beautifully woven cotton garments. Recognizing the cotton cloth, he thought he had reached India, because he and his crew had heard about the cotton that grew in that far-off land. In time cotton became highly regarded by Europeans, and the Spaniards frequently demanded tribute from the Aztecs, Mayas, and Incas in the form of cotton cloth.

The cotton plants cultivated in India and America were very much alike. And in both places the ancient processes of making cotton cloth were practically the same! How did the same plant happen to be used in the same way in two widely separated hemispheres? Did the people of one country carry it to the other, along with the knowledge of the art of weaving? Scientists and students of history can only guess at the answer. What is your guess?

As in the production of many other cultivated plants, the United States has jumped into the lead among the nations of the world in the production of cotton. It now produces nearly half the cotton of the entire world, as the map on page 14 will show.

Exercise. Make a list of all the manufactured articles you can think of which contain cotton. How many items do not come under the classification of clothing?



This map shows what the United States has achieved in the production of cotton

NEW ADVENTURES IN PLANT CULTIVATION

Story of the Potato. The crops which we have just studied, together with flax, rice, barley, millet, and a few others, have been cultivated in some parts of the world since prehistoric times. Let us now consider some crops which have been brought under cultivation more recently.

Among the most important is the potato. White potatoes grew wild in tropical America before they were cultivated by the Indians. Several wild varieties still grow throughout South and Central America. Another wild potato plant may be found today in Colorado, with potatoes no larger than marbles. Potatoes were unknown in Europe until the sixteenth century, when they were brought there from America by Spanish and English explorers. Today they are among the most important crops in the world.

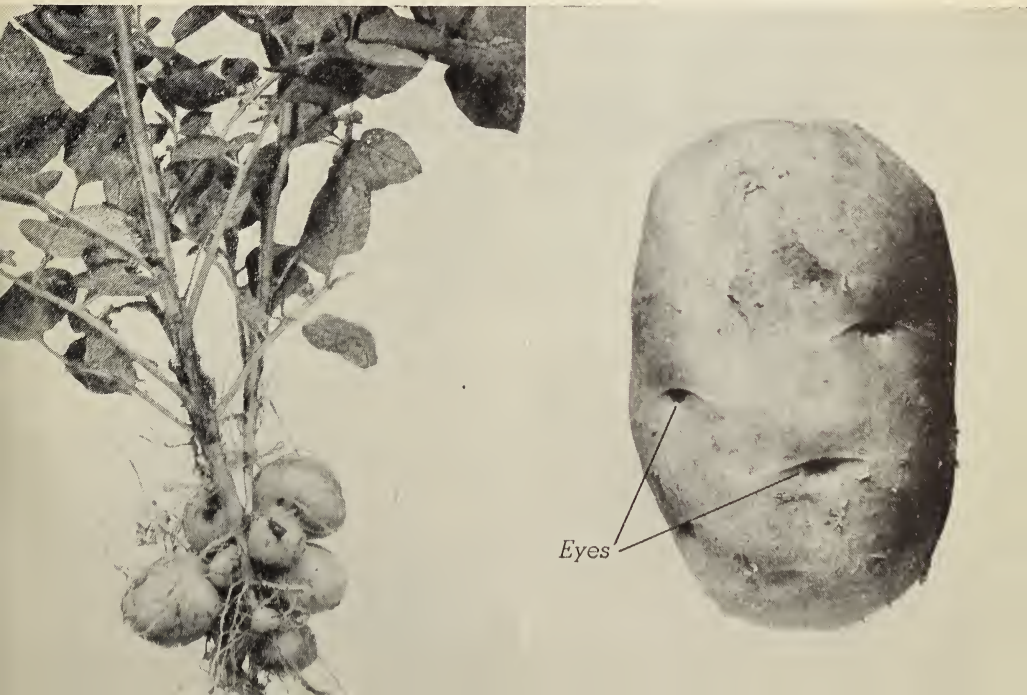
Like most other cultivated food plants the potato has increased in size with the passage of time. A writer of the seventeenth century described potato plants, then grown as a luxury in Virginia, as having potatoes "as large as a walnut and some larger." Imagine how surprised this gentleman would be if he could return to earth and see our modern potatoes, many of which weigh more than a pound apiece and are full meals in themselves.

The white-potato plant shown below develops slender underground branches, upon the ends of which grow the *tubers*, or potatoes. These tubers are swollen underground stems in which starch made by the plant is stored. The "eyes" of the potatoes are leaf buds.

When the seeds from the flowers of a potato plant are sown, the new plants almost always are inferior to the parent plants. They return to the puny condition of their ancestor, the wild potato. For this reason potatoes are

The white potato is a swelling on an underground stem of a potato plant (left). The "eyes" (right) are leaf buds, each of which is capable of producing a new plant

Hugh Spencer



usually grown from *cuttings*, for which pieces of the tubers of the previous year are used. Each piece of tuber cut for this purpose must contain at least one "eye." Each "eye," as shown on page 15, is capable of producing a new plant.

Exercises. How to find out how potatoes give rise to potato plants. Place a potato in a flowerpot and cover it with sawdust. Moisten the sawdust and place it in a warm spot. Keep the sawdust moist. After a time the potato will sprout and you may see how new potato plants form.

Cut a potato into pieces, so that each piece contains one "eye." Plant each piece as indicated above, and see what happens. Why do farmers usually cut potatoes so that each piece planted contains two or three "eyes"?

Rubber. Rubber is another product of modern times. When Columbus came to America he found Indian children playing with rubber balls. He had never seen or even heard of this strange material. Since that time we have discovered a surprisingly large number of uses for rubber,—rubber shoes, rubber coats, erasers, elastic goods, rubber cement, and many others,—but it is the automobile that has made rubber a modern necessity.

Until shortly before the World War of 1914–1918, most of the world's rubber was obtained from wild rubber trees of the tropical rain forests. Natives slashed the bark, collected the milky fluid that leaked out from the cuts, and molded it into balls of rubber. In time, however, the demand for rubber became greater than the supply. Slave-drivers pushed the natives without mercy; in the Belgian Congo, especially, dark men suffered tortures in the white man's attempts to keep up with the demand.

To meet this problem, the British and the Dutch successfully planted Brazilian rubber trees in the East Indies.

In the early 1920's a leading American tire-producer leased a million acres of land in Liberia, on the west coast of Africa, for the same purpose and with the same success. In these plantations the trees are planted close together, so that long journeys from tree to tree are avoided. Trained rubber-tappers, intelligent and well paid, do the work formerly done by unskilled half-civilized savages. The old process of preparing the rubber has given way to modern methods which not only produce better rubber for the manufacturer, but produce it more cheaply.

Exercise. From time to time men have tried to find new sources for rubber. They have tried to make artificial rubber, and they have tried to develop natural materials with the elastic and waterproof nature of rubber. The familiar milkweed and the less familiar Mexican guayule plant have been studied with this end in view. See what you can discover about man's success in these undertakings.

This village houses workers in a modern West African rubber plantation

The Firestone Tire and Rubber Co.

Quinine. Quinine, a drug which helps to make it possible for white men to live in the tropics, is itself a product of the tropics. It is made from the bark of the cinchona tree (pronounced sin ko′na), shown on page 19. These trees grow wild in the forests of Ecuador, Peru, and Bolivia, in mountainous regions a mile or more above the sea.

Ever since it was discovered that quinine will cure malaria, the Indian natives have been searching for cinchona trees, cutting the bark from them and drying and selling it. As a result, many of the wild trees have been destroyed. But the production of quinine, like the production of rubber, has been modernized. About 1860 some young cinchona trees were taken from South America by the Dutch and planted in the East Indies. Today the Dutch have almost complete control over the quinine market.

This skilled workman is tapping a rubber tree by removing some of the bark. If he cuts one twenty-fifth of an inch too deep, he will injure the tree

Alfred Palmer from Black Star

Exercise. Make a list of other plant products used in medicine. Ask a druggist to help you. Report to your class on some of the things you have found.

The Place of Uncultivated Plants in the Modern World. Not all the adventure of using plants has to do with plant cultivation. Modern man, though not to nearly so large an extent as primitive man, draws upon the wild vegetation of the earth for his needs. Part of the fun of living or visiting in the country is that not all the useful plants are tame. There are many wild ones which yield a variety of interesting products.

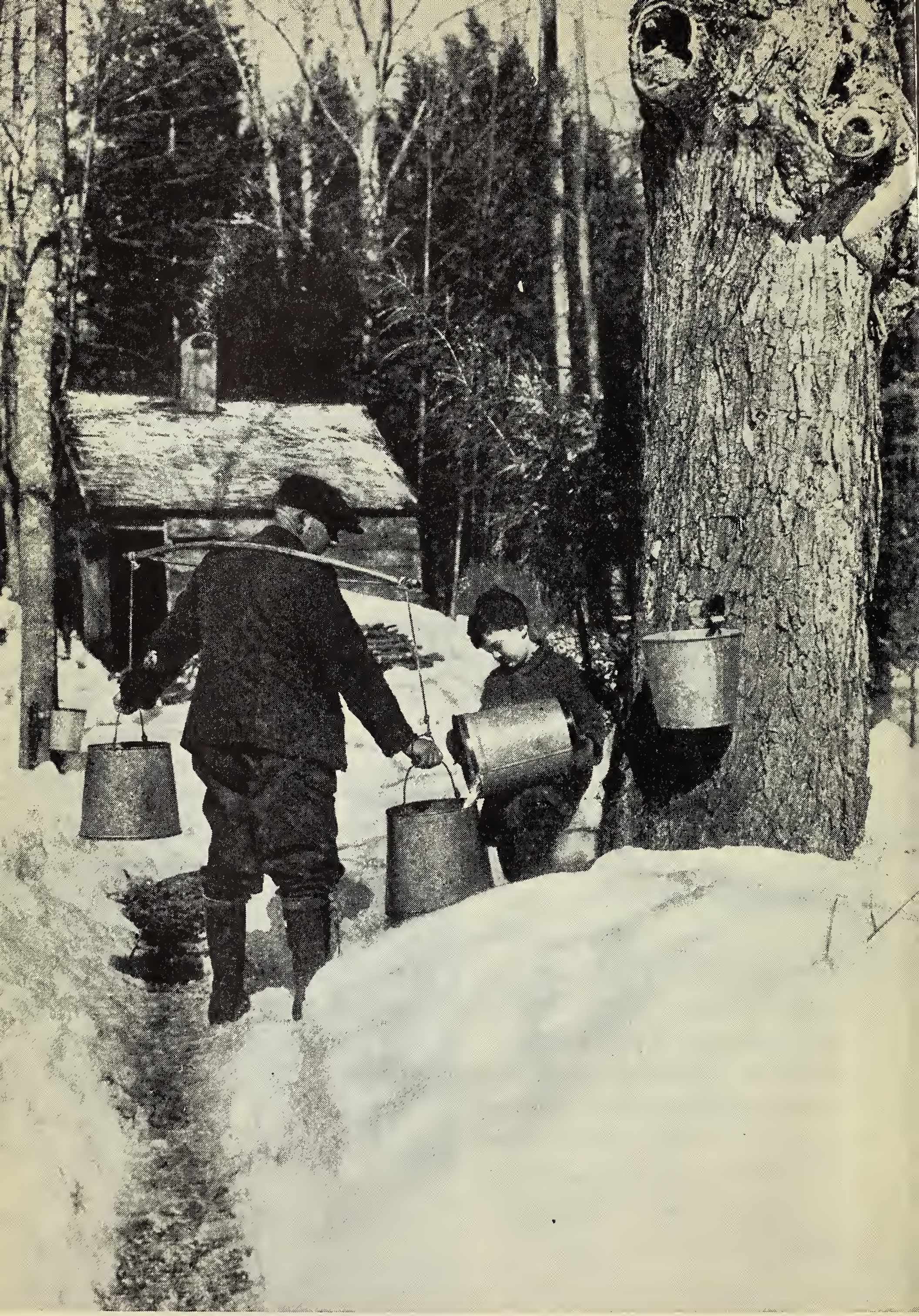
People who live in the country know a number of small plants that make good greens—better than spinach or beet tops, they say. Have you ever eaten milkweed boiled with a bit of salt pork? Do you know the taste of wild mustard, of the young spring shoots of brake ferns, of pusley, dock, pigweed, dandelion, or cowslip? Glad indeed is the rural housewife when she can pick her first basket of wild greens in the springtime. And the city dweller who has never eaten them has missed a pleasant experience.

There are blueberries too. Nearly all the blueberries in city markets are picked from wild bushes. If you live in the city, perhaps you have spent a summer vacation on a farm in New Hampshire, New Jersey, or Wisconsin. Perhaps you have armed yourself with pail and sun hat and gone blueberrying. If you have, you probably found it great fun.

There is one product of the Northern woods in which boys and girls are especially interested—maple sugar. Early each spring, or perhaps only once in two years, boys and men go out to the groves of sugar maples in Vermont and northern New York, and drill holes, or "taps," in them, as shown in the photograph on page 20. At that time of year the sap is passing up and down tubes in the outer part of the wood of the trees. Some of it

This man is gathering cinchona bark for the manufacture of quinine

Horace Bristol from *Life* Magazine



Gendreau

Maple sap runs early in Vermont

flows out through the taps and is caught in pails. When the sap is "boiled down," or evaporated, maple sugar remains.

As yet it has not been found worth-while to cultivate these sugar maples in the same sense that we cultivate beets or sugar cane. Nevertheless, sugar trees are well cared for and tapped with moderation. A maple must be about thirty years old before it is large enough to be tapped.

Exercise. Make a list of the wild plants in the vicinity of your home which are used for food, medicine, decoration, or any other purpose. See who can make the most nearly complete list.

The plants which we have briefly treated above are only a small number of those that are valuable to man, but they will serve as well as a fuller list to illustrate a world-wide truth. *Wherever and whenever plants have become economically important to man, he has sought ways of cultivating and improving them.* He has studied their needs, their habits of growth, and their fruits. He has watched them and toiled over them in order to enjoy their products. Let us now study in more detail just how he has done this.

HOW CROPS ARE IMPROVED

The Process of Selection. Long before the beginning of written history men had learned that some trees bear bigger or sweeter fruit than others of the same kind. Every country boy knows that this is true today. In the same way, early farmers learned that some plants of grain bore larger heads or made better meal than others. They learned to save and use some of the seed from these more desirable *varieties*, as they are now called. In other words, they *se-*

lected the best plants for seed, just as farmers do today. This process of selection is one of the chief ways by which crops have been—and still are being—improved.

Slipping. In the orchard and vineyard, seed selection is not so effective as it is in the field and garden. For a variety of reasons too technical to discuss here, the seeds of fruit plants are likely to produce inferior fruit. Fortunately, there are ways of continuing a productive line of fruit plants without depending on the seeds. With the grapevine and raspberry bush, for example, a piece of the vine or bush can be bent over and covered with earth. After a time the buried portions develop roots. These portions can then be cut loose from the old plant and transplanted wherever needed. They will produce just as good fruit as the plants from which they came.

Many plants can be grown by an even more simple process, known as slipping. A cutting, or *slip*, is taken from a parent plant, as shown on the opposite page. This is then trimmed back and set out in wet peat moss or in moist sand or dirt. It will soon develop roots and begin to grow. It will be like the parent plant because it *is* the parent plant. It is a true "chip off the old block."

Exercise. Elms, willow, forsythia bush, geranium, and white potato plants can all be grown from slips. Get cuttings of some of these plant types and see for yourself.

Grafting. With apples, pears, peaches, oranges, and the like, the problem of cultivation is not so simple. Their twigs do not form roots easily when buried, either before or after they are cut loose from the parent tree. But somehow man discovered that a twig could be cut, slipped into a split branch of another tree of the same kind so that the inner bark of the two touched, sealed with wax, and made to grow into a branch of the new tree. By means of this process, known as grafting, desirable fruit can be produced on the roots and stem of any seedling by simply replacing its branches with those from a better source. The illustration on page 24 shows how a plant graft is made.

Budding. An even more delicate process than grafting is used a great deal today, especially in the cultivation of peaches and pecans. This is called budding, which is the transfer of a bud with a bit of attached bark into a slit of another tree. The wound is sealed and wrapped, and in time the bud grows into a branch which produces fruit as good as that of the tree from which the bud was taken.

Exercise. After making a careful study of the methods used in grafting and budding, prepare some twigs to show how these methods are carried out in practice.

These girls are cutting and planting slips from a rosebush

Slipping, grafting, and budding are all methods of cultivation which are based on selection. *All these methods improve the crop, but they do not produce better plants than those from which the slips, grafts, and buds were taken.* Better plants, however, can be produced, as we shall now see.

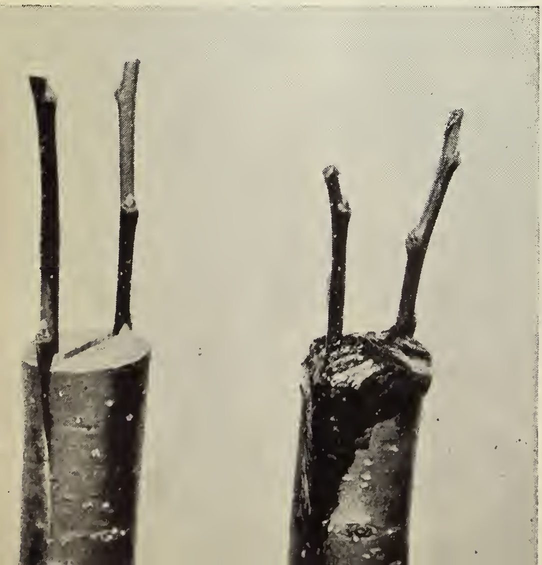
HOW NEW VARIETIES OF PLANTS ARE PRODUCED

Sports. Now and again plant (or animal) types will give rise to offspring which are very different from their parents. Gardeners and animal breeders call these freakish offspring "sports." Sports are simply plants or animals which for some reason or other have new characteristics or qualities. The Concord grape, for example, first appeared as a sport.

By growing very large numbers of plants and searching them carefully, it is sometimes possible to find sports with desirable characteristics which, in the language of the scientist, will "breed true to type." This means that they can be made to give rise to other plants like themselves. By the careful cultivation of sports, the useful plants of the earth have been—and will doubtless continue to be—increased.

In grafting, twigs cut from one fruit tree are placed in a slit in the branch of another fruit tree (left) and then sealed with wax (right)

Hugh Spencer



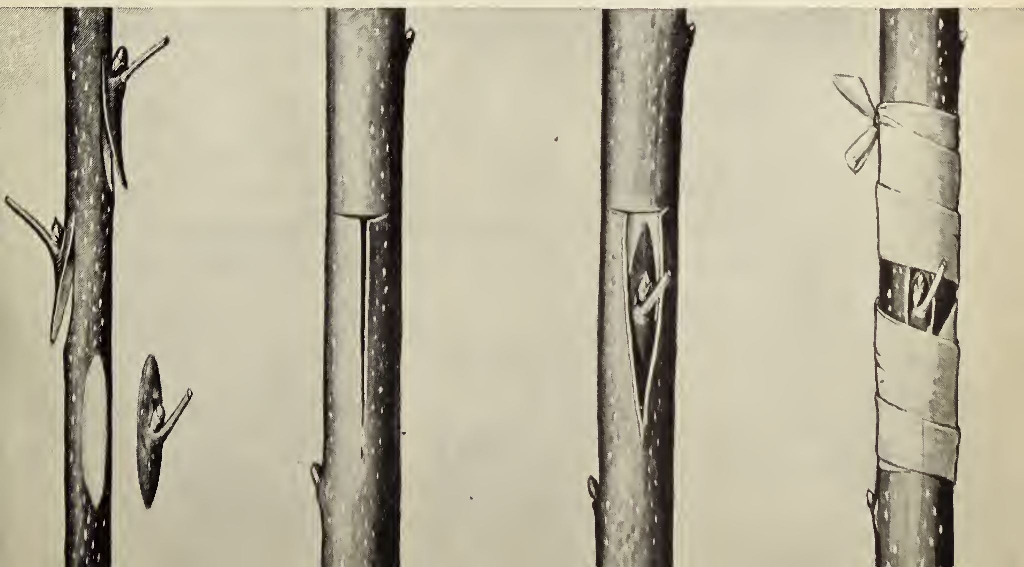
Crossbreeding. Sports are accidents of nature which appear from time to time through causes that are poorly understood. In recent years it has been found possible to increase the number of sports by exposing seeds and flower buds to X rays and radium. The resulting sports, however, are generally of no use.

Do you see why men have not been content to wait for nature to develop new varieties of plants through sports? Men are impatient for results, and they are not content to depend chiefly on luck. They have sought a way of speeding up the development of useful new plants, and they have found it in the process of crossbreeding.

Seeds are tiny new plants which, like most living things, come from *egg cells* that have been fertilized by male, or *sperm, cells.* In most cases the egg cells of any given type of plant are fertilized by male cells from the same type of plant. The result is seeds which grow into plants of the same variety.

Sometimes, however, the egg cells of one type of plant are fertilized by sperm cells from plants of a slightly different type. The result is plants which differ somewhat from both their parents. These new plants are called *hybrids*, and the process by which they are developed is known as cross-fertilization or crossbreeding.

These are the four steps in the process of budding



Hybrids. Natural hybrids may appear when plants (or animals) of two closely related groups live fairly near together. Many hybrids are less well fitted to the environment in which they find themselves than are their parents; more often than not they die without leaving any descendants. But occasionally there appears a hybrid that is better adapted to its environment than either of the two groups to which its parents belonged. In this case it will probably live, and it may produce offspring.

Some of the offspring may be superior individuals. These may in turn produce other superior individuals. A succession of superior individuals may within a few generations crowd out the older stock altogether. Most hybrids do not breed true to type, but an occasional one does. Several different varieties of pigeons, ducks, butterflies, primroses, wheat, and blueberries are examples of successful natural hybrids.

Exercise. Do you believe it would be possible to have a hybrid of corn and sugar cane which would contain the valuable starch of the first and the valuable sugar of the second? If so, why? If not, why not?

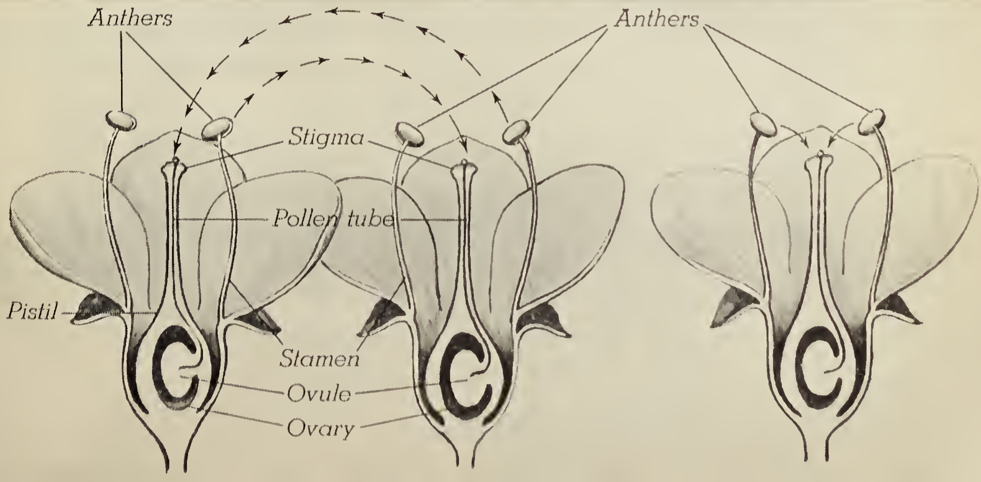
What lies behind this process of hybridization? What makes any offspring, either plant or animal, what it is? Consider a grain of wheat produced as a cross between the two well-known varieties, Red Fife and Hard Red Calcutta. It might produce a plant that would ripen early like the Calcutta and yield abundantly like the Red Fife. It might, on the other hand, produce a plant that would ripen late like the Red Fife and yield little or nothing like the Calcutta. In either case its characteristics would be inherited from its parents.

How Plants Reproduce. Before we can understand how the traits of plants are handed down from generation to generation, we must understand how plants reproduce. The secrets of inheritance lie in the egg cell and the sperm cell which unite to form the new individual. In a flowering plant the sperm cells are carried in the grains of pollen which form in the *anthers* at the end of the *stamens.* The egg cells are contained in the *ovules,* which are located in the *ovary* at the base of the *pistil.* See diagram below.

Before a seed can be produced, a sperm cell from a *pollen grain* must reach the *stigma* at the end of the pistil and from there work its way to the egg cell within the ovule. The combination of sperm and egg produces a *fertilized egg,* and from the fertilized egg the seed develops. Under normal conditions a new plant will grow from the seed.

The process by which pollen is transferred from the anther to the stigma is called *pollination.* Some flowers may be self-pollinated; others are always cross-pollinated. In *self-pollination,* pollen from an anther of one flower is transferred to the stigma of the same flower. In this case the sperm cell and the egg cell with which it combines are both produced by the same flower. In *cross-pollination* there is transfer of pollen from an anther of one flower to the stigma

Here are the two ways in which plants reproduce.
Cross-pollination is shown at the left; self-pollination, at the right



of a different flower. In this case the sperm cell and the egg cell with which it combines are produced by different flowers. These two processes are illustrated on page 27.

What Mendel Discovered. Are there any general truths about inheritance which plant-breeders have learned? The answer is "yes." And the man who discovered the most important of these principles was Gregor Mendel, a monk whose hobby was gardening. Let us see what these principles are by reviewing some of Mendel's work. (As you read the following paragraphs you should be sure to check each statement with the diagram on the opposite page, to keep from getting confused.)

In a very famous experiment Mendel took some pollen from a *dwarf* garden pea plant and placed it on the stigma of a *tall* garden pea. At the same time he also put pollen from the tall pea plant on the stigma of the dwarf pea plant. In other words, he artificially cross-pollinated the two kinds of pea plants so that the offspring of both plants would inherit the traits of both plants.

When the seeds ripened in the parent peas he planted them. What would the offspring plants be like? Would some of them be short and others tall? Would all be halfway between their parents in height? Mendel watched with eager interest. Imagine his surprise when he found that *all the new plants of this first generation were tall!*

What had happened to the trait of dwarfness? Mendel found out when, after allowing the tall first generation hybrids to fertilize themselves, he planted their seeds. *The plants that came from these seeds (the second generation) were both dwarf and tall, about one dwarf one to three tall ones.* He found out, in other words, that the trait of dwarfness, which did not appear in the first generation at all, cropped out in the proportion of 1 to 3 in the second generation.

After allowing the dwarf plants of this second generation to fertilize themselves, he found that all gave rise to dwarfs in the third generation. These dwarfs and their descendants gave rise to dwarfs in all following generations. In other words, *all the dwarfs "bred true."* The trait of tallness completely disappeared.

Only one third of the tall plants of the second generation gave rise to tall plants in all succeeding generations. In other words, *only one third of the tall plants of the second generation bred true.* The remaining two thirds gave rise

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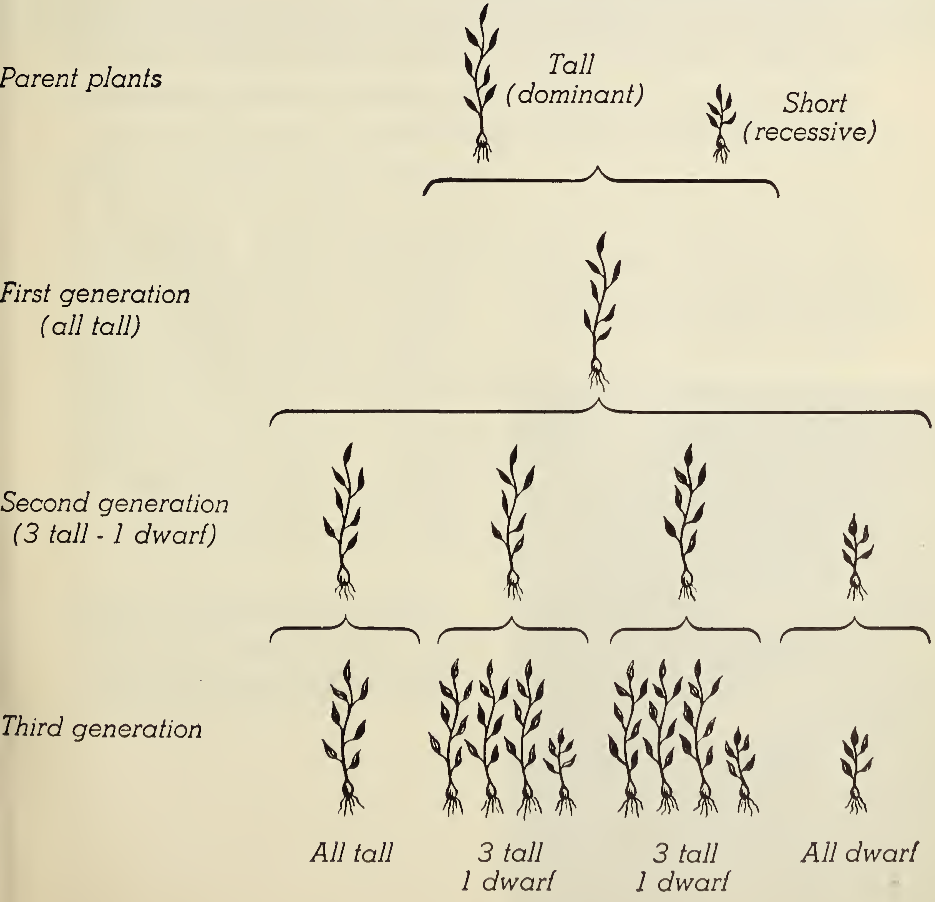
This diagram illustrates Mendel's experiment on the crossbreeding of tall and short garden pea plants



to dwarf and tall plants in exactly the same 1 to 3 proportions which we observed in the first generation.

No matter how often he repeated this experiment Mendel always got the same results. He studied the inheritance of many different traits in crossbred plants besides dwarfness and tallness. He studied particularly the colors of seeds and flowers. But his experiments always led to the same conclusions.

They proved in general (1) that plants inherit the characteristics of their parents not in a hit-or-miss fashion but in definite proportions; (2) that some characteristics of the parent plants tend to show up in the offspring of the first generation while others do not; (3) that the characteristics which do not show up in the first generation of offspring may do so in the second.

Dominant and Recessive Traits. Mendel observed that in many crossbred plants certain characteristics tend to appear more frequently than others. In the experiment described above, for example, tallness appeared more frequently than dwarfness. Tallness in Mendel's term was a *dominant* trait because it tended to dominate, or come forward. Dwarfness was a *recessive* trait because it tended to recede, or stay in the background. Only those plants which are pure dominants or pure recessives breed true.

This man is making a cabbage plant self-pollinate by placing the anthers of a flower on the pistil of the same flower

Ferry Morse Seed Co.

Blended Inheritance. In many cases where plants with contrasting traits are crossed, nei-

In this monastery garden Gregor Mendel made some of the greatest discoveries in the history of science

ther trait is dominant. In such cases the offspring of the first generation may all show a mixture of the traits of both parents. For example, a red-flowered four-o'clock plant when crossed with a white-flowered four-o'clock plant will give rise to *pink-flowered* plants in the first generation if neither red nor white is a dominant trait. The pink-flowered plants are examples of blended inheritance.

Even in blended inheritance the traits of the parents come out unmixed and in definite proportions in the second and later generations. The pink-flowered four-o'clocks give rise to other pink-flowered four-o'clocks, but also to definite percentages of plants which have the white and red flowers of their grandparents.

The Use of Mendel's Discoveries. What Mendel found out in his monastery garden has become tremendously valuable to the world at large. Knowing that pure dominants and pure recessives always breed true, plant-breeders can now intelligently search for these and breed for the traits they want. A great many plants, indeed, have already been definitely improved through the application of Mendelian principles. Since these principles apply also to animals, they have been equally a boon to the breeders of animals. In the whole long struggle to improve the plant and animal resources of the world, no man has contributed more than Gregor Mendel.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Practically no progress in farming was made until after the day of Mendel.

2. Wild wheat is still used for food in the region round Palestine.

3. Corn originated in Europe and was carried to America by early English and Spanish explorers.

4. Sugar cane was first grown by the early Egyptians.

5. Cotton was first cultivated in India and did not find its way to America until the sailors of Columbus brought it there.

6. All wild potato plants have disappeared from America with the advance of civilization.

7. The potatoes grown from the seeds of American potatoes are the best in the world.

8. Most of the world's rubber supply comes from the sap of rubber trees which grow wild in the tropical rain forests.

9. As civilization advanced, men gradually stopped using wild plants for food until now not a single wild plant ever finds its way to the table.

10. Slipping is the process of planting only the seeds from the most desirable varieties of plants and thus increasing the number of desirable plants.

11. Making a bud from one tree grow on another tree is known as grafting.

12. A sport is a plant which for one reason or another cannot be made to reproduce.

13. A hybrid is a new variety of plant that always gives rise to other plants exactly like itself.

14. First-generation hybrids always show the traits of both their parents in definite proportions.

15. A dominant trait is one that tends to diminish, or stay in the background, in experiments in plant-breeding.

Questions for Discussion

1. What evidence can you think of which would support the statement that agriculture is more ancient than history?

2. What importance is there in the fact that the United States owns about 85 per cent of the world's automobiles and yet controls less than 1 per cent of the rubber output of the world?

3. You may have seen a horse-chestnut tree with one branch having white blossoms and all the other branches having pink blossoms. Can you explain what had happened?

4. Is it possible for an apple tree to produce two different kinds of apples? Explain.

5. Is it possible to say in all cases that mixed breeds are inferior to pure stocks? What must you consider before you make your answer?

Things to Do

1. Make a study of some of the plants cultivated by the American Indian. Read *Columbus Came Late*, by Gregory Mason.

2. Make a wall chart showing the original homes of various cultivated crops. You may get some help from Parker and Cowles's *Book of Plants*.

3. Make a study of some of the work done in improving wheat or some other plant. Your neighborhood florist or nurseryman might be able to help you.

4. Luther Burbank was famous for his experiments with plants. Find out what you can about his work and report on it in class.

CHAPTER TWO

How Do We Make Use of Animals?

THE CHANGING RELATIONS OF ANIMALS AND MEN

When Meat was Scarce. The cultivation of plants has been one of the chief occupations of men since the beginning of their history. The domestication of animals has also been one of the chief occupations of men. These two occupations have developed side by side, and it is fitting that we should study them side by side in this book. Let us then devote this chapter to animals, as we devoted the last chapter to plants, thus rounding out the story of man's conquest of the living world.

Imagine yourself a very early man in a world of savage beasts. You have not yet discovered the art of making tools and weapons. You wander about in search of food, but because you are unarmed your menu is strictly limited. You eat roots and berries when you can find any that taste good. You hunt for small weak animals that you can kill without danger to yourself. But you keep out of the way of the larger animals who are also looking for food, perhaps with their eye on you.

If you live near the seashore, you find oysters and clams which put up no fight at all and provide a tasty variation from roots and berries. You catch insects and chew out their juices. Perhaps this kind of food does not wholly appeal to your modern taste, but as a very early man your tastes are shaped by necessity. Unarmed in a hostile world, you are lucky to be eating at all!

How long mankind had to live on so narrow a diet as we have imagined above, nobody really knows. We do know that great heaps of seashells—the remains of ancient feasts—still may be seen along many seacoasts today. We know that until man learned to use fire he had to be content to eat simple food, and to eat it raw. We know that until man had invented weapons he must have avoided the larger animals, because primitive man with all his limitations was probably no fool.

How Men Became Hunters. This does not mean, of course, that very early man never had a taste of red meat. Even today hungry people will eat animals that have been killed by accident or by other animals. African pygmies make pitfalls to trap elephants and then camp round the victims, sometimes for weeks, until all the flesh is eaten. Primitive men of the past undoubtedly did likewise.

In the course of time, men found ways of extending the variety and increasing the supply of animal food. They probably first used sticks and stones to kill small animals, and later selected or modified sharp-edged stones into cutting and piercing instruments. When they fastened stones upon handles and lengthened their arms by inventing the throwing stick and the bow, they were ready to strike at more powerful game without giving the game a chance to strike back. Only then were they ready to become the hunters that we ordinarily think of them as being.

Aided doubtless by their growing use of spoken language, primitive men learned how to band together in groups for hunting powerful animals. They thus crept up on herds of grazing animals against which one man, even if well armed, might be helpless. We can only guess how they learned to hunt in this fashion, but we know that they did

Through the invention of weapons primitive man was able to enjoy the pleasure of fresh meat

learn because ancient pictures on the walls of caves show them doing it. Anyone who has seen a pack of greyhounds run down a jack rabbit, or a group of wolves at the heels of a deer, knows that animals also hunt together. Perhaps primitive men learned how to hunt animals by studying how animals hunt.

Group hunting was a very important development in man's history. It meant that he could leave the tree-clad regions of the earth with their fruits, small game, and shelter. He could go forth upon the great grasslands where the herds of wild cattle fed. Thus probably man's use of grazing animals began, a practice which has never since ended. Through it men have been able to live in dry regions which afforded them little vegetable food.

Department of the Interior, Ottawa, Canada

Reindeer are the cattle of the Far North

How Hunters Became Herdsmen. Hunting at best is both strenuous and dangerous. Presently it was gradually abandoned for an easier and safer way of obtaining meat and other animal products. Young animals of various kinds were caught and raised in captivity. Some, like the dog and the pig, probably lurked round the camp waiting for garbage, much as rats lurk round a dump today. When men learned that wild cattle grew tamer when fed and protected from other animals, the stage was set for the entrance of the herdsman.

Nobody knows exactly how primitive men slowly turned from hunters into herdsmen, but the story of the Eskimo may possibly give us a clue. Like the primitive men of long ago the Eskimo was first a hunter. He had no domestic animals except the dog, and in most cases no permanent home. His food was the meat of wild animals, the very name "Eskimo" meaning "eater of raw flesh."

Soon after the United States purchased Alaska, our government became interested in improving conditions among the natives. Recognizing the fact that people in the hunting stage of civilization never have a dependable source of food, the government employed scientists to see if they could provide these people with domestic animals. Such animals had to be adapted to live and multiply in the climate of Alaska upon the native food.

The reindeer, already domesticated in Siberia and northern Europe, looked like just the animal. It can eat the moss that grows on bleak arctic pastures. Its milk is good and its flesh tender. It can endure severe cold. Accordingly, 1200 reindeer were introduced into Alaska in 1891. With them came a band of Siberian herdsmen to teach the Eskimos how to care for these new animals. So successful was this experiment that forty years later there were more than 700,000 domesticated reindeer in Alaska and Canada.

Today the reindeer of Alaska supply their owners with milk, meat, and leather. Often the supply is so abundant that a considerable surplus can be exported. Have you ever eaten a reindeer steak? This meat is finding a place on the menus of restaurants and even on dinner tables of private homes in the United States. If there were enough demand for it, reindeer meat could be an important item in our food supply. A herd of reindeer is shown on the opposite page.

The reindeer made it possible for the Eskimos to progress in a single generation from the stage of huntsmen to that of herdsmen. In some such way the primitive men of earlier ages probably made the same kind of progress.

Exercise. Read in Van Loon's *Story of Mankind* or Wells's *Outline of History* about the early history of hunting and herding.

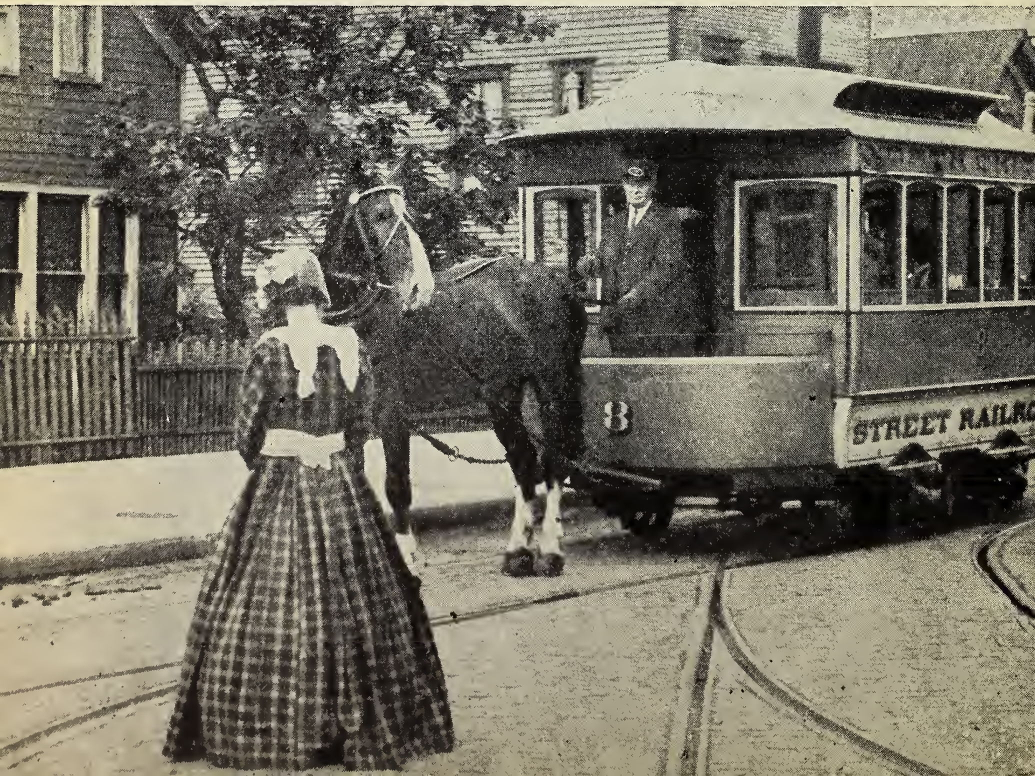
Modern Uses for Animals. Abundant meat was doubtless the chief benefit from the early domestication of animals, but the use of hides, wool, milk, and labor followed quickly. These products in turn led to the arts of tanning, textiles, dairying, and the invention of sleds, plows, and wheels.

For a long time in human history animals were used for power, as the term "horsepower" suggests. Railroads were developed for the use of horse-drawn cars; the automobile is an outgrowth of the old horse-drawn buggy. Grinding mills were operated by oxen, churns by dogs or goats. Though machines have pretty generally put animals out of the power business in highly civilized countries today, domestic animals still have their place and their uses.

A great deal of modern invention has to do with the better preparation of animal products such as meat, wool, and leather. With better equipment for long storage and shipment of meats, for example, the packing industry has be-

Not so long ago "horsepower" really meant horse power

Underwood and Underwood



Galloway

n this modern "egg factory" poor workers are sent to the butcher, and exceptionally good workers to the breeder

come highly mechanical. Even the operations of the farm have felt the influence of mechanical industry. Cows are milked by machinery, bees are kept in standardized hives, and chickens are raised in small, sanitary pens which can be truly called "egg factories." Thus the world changes, and our use of animals with it.

Exercise. Cheese, milk, leather, and bone fertilizers are a few of the animal products whose development for the market is done today by highly scientific methods. Look up the facts about the production of one of these products and make a report for your class.

When Is a Wild Animal Not Wild? Just what is a domesticated animal? When in the process of domestication does a wild animal cease to be wild? This question may at first seem easy. The calf in the barn is domesticated; the fawn in the meadow is wild. The puppies in the barnyard are domesticated; the young foxes in the woods are wild. The ducks in the henyard are domesticated; the ducks that you see as they fly south in the fall are wild.

But suppose you take a baby raccoon or a baby lion and tame it. It drinks milk from a bottle and later laps it from a saucer. It makes an interesting pet—until it bites you. It isn't domesticated, nor can you make it so. Similarly, you may feed squirrels and coax them into your parks or dooryards. Next year or perhaps the year after they build nests in your attic. They steal corn from your barn. But they are not really domesticated. They do not depend upon you, although they may use you for their own advantage.

Men herd bison in reservations, as shown in the photograph on the opposite page. There they live more or less

This baby lion is not so friendly as you may think

Herbert Gehr from *Life* Magazine

American bison (incorrectly called "buffaloes") differ little from their wild ancestors

unnaturally; but they produce offspring, and their flesh and skins may be useful. Though they would die without the protection of man, they are not domesticated because they differ very little from their wild ancestors. *Truly domestic animals (1) are unlike their wild ancestors in appearance; (2) depend on man; (3) live in a manner and in places prescribed by man; (4) breed in captivity.* Unless an animal meets *all* these conditions, it is not domesticated.

Exercise. Which of the following animals are truly domesticated and which are not: Canary birds in cages, cows in a pasture, giraffes in a circus, the birds taking a bath in a garden pool, the cat that stalks the birds, the dog that chases the cat, zebras in a zoo, the elephants that work in the teak yards of India? Give a full account of the reasons for your conclusions.

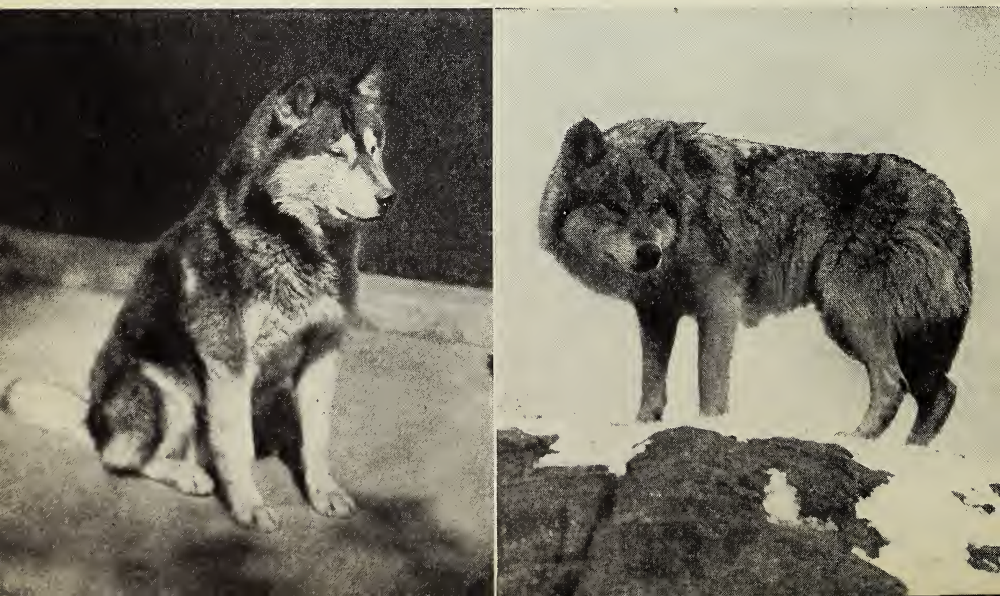
The Dog, Oldest Domesticated Animal. The dog was perhaps the first of all domesticated animals and is still the most widely loved. He was man's companion as early as the New Stone Age, but whether man adopted the dog or the dog adopted man, nobody knows. We do know that men and dogs were companions long before the beginning of written history. Bones gnawed by dogs perhaps ten thousand years ago are found in the dump heaps, or "kitchen middens," of early man in Europe.

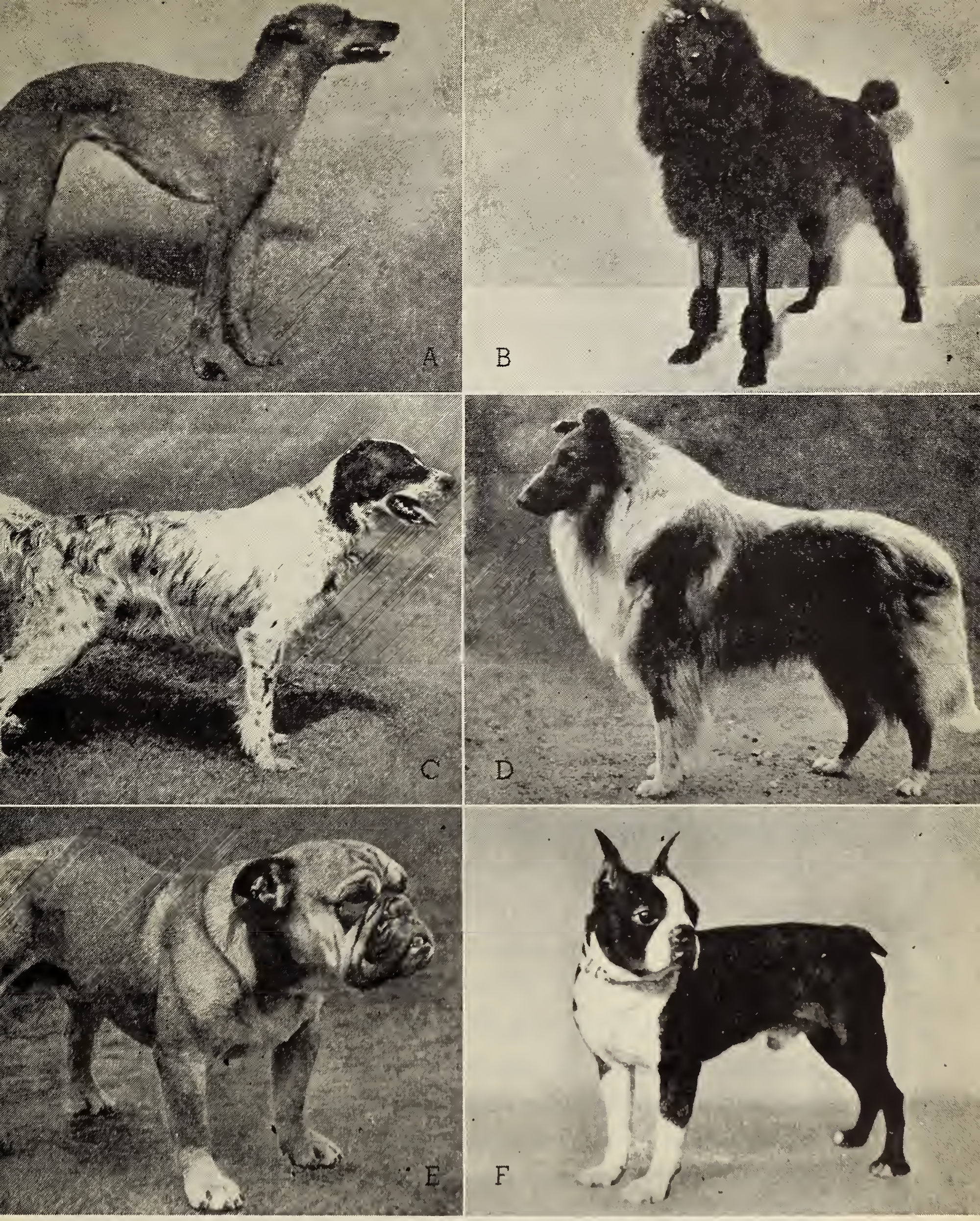
The origin of the dog is uncertain. Dogs are native to all parts of the world. Those in our country today are so closely related to foxes, wolves, and coyotes that they not uncommonly crossbreed with them and are thus constantly changing. Indeed, dogs often disappear from farms in localities where wolves are plentiful, only to be seen later running with the wolves. It is said that arctic explorers are often afraid to shoot into a pack of wolves lest they prove to be Eskimo "huskies." Perhaps the illustration below will show why.

Exercise. Many good stories have been written about wild, half-wild, and half-tame dogs. If you have not already done so, you might like to read Jack London's *Call of the Wild* and *White Fang*, or some of Albert Payson Terhune's dog stories.

Do you think you could tell the dog (left) from the wolf (right) at a hundred yards?

N. Y. Zoological Society





A, E, Acme; B, Keystone; C, Colonel G. A. Taylor, Norwottock Kennels, Hadley, Mass.; F. Roberts

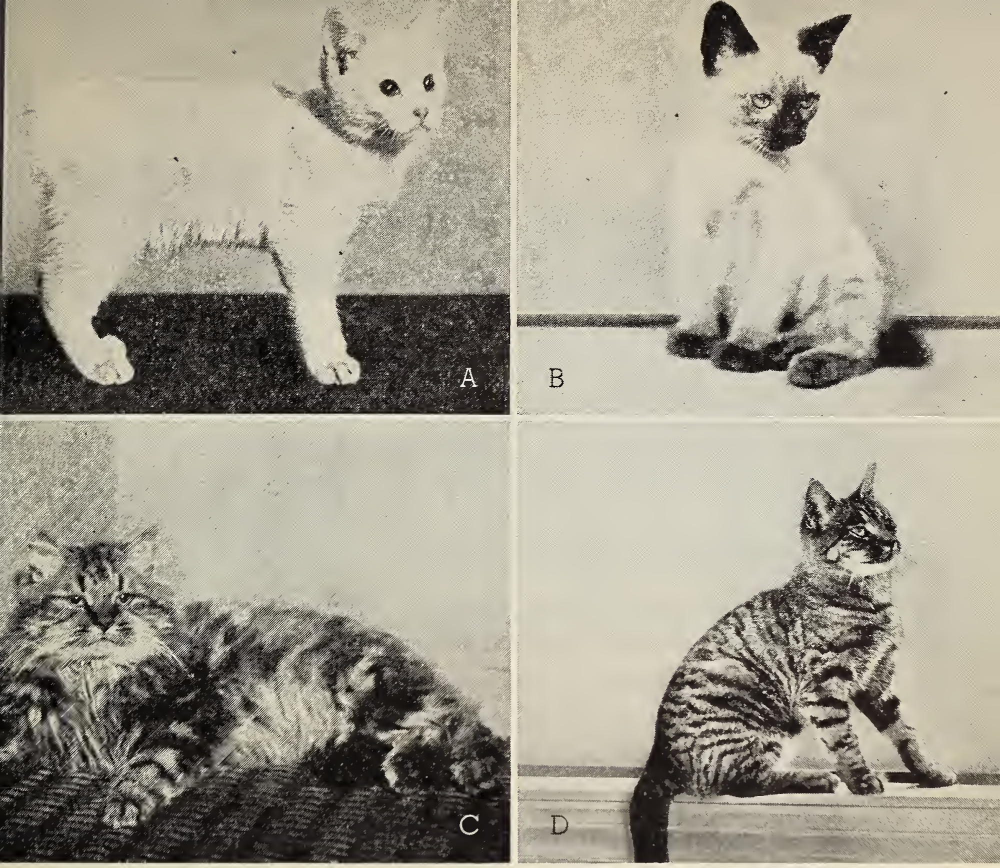
Do you know these six breeds of dogs?
How many other breeds could you recognize?

One hundred and four distinct breeds of dogs are recognized today by the American Kennel Club, and there will doubtless be more in the future. When you think of all the types that lie between the Russian wolfhound and the bull terrier, the German police dog and the tiny Pekinese, you will not be surprised at that number.

These different varieties of dogs have been developed deliberately for different purposes by the processes of selective breeding which we studied in the last chapter. Look at the types shown on page 45. The whippet has been bred for speed, the collie to protect sheep, the poodle for tricks on a stage, the bulldog for fighting, the setter for hunting, the Boston terrier for a pet. Through application of the principles of animal-breeding it is possible to breed a dog to satisfy almost every fancy.

The Cat. Cats were probably first domesticated as sacred animals in connection with the early Egyptian religion, and there are still many superstitions associated with them. They belong to the family which includes the lion, tiger, and leopard, and are native to all parts of the world. There are only a few truly different types of domesticated cats, and these are shown on the opposite page.

The domestic cat has never really "earned its salt." It has caught mice, to be sure, and it has contributed a cheap imitation of expensive furs. Aside from that it merely eats what is given it, hunts when it must, and multiplies rapidly. It is a clean and beautiful animal, though in most cases less friendly to man and less intelligent than the dog. When necessary it is still able to take care of itself. Indeed, there are more stray cats in our country today than there are cats with owners. The cat is a splendid example of an animal that is well adapted to its environment.



A, Wide World; B, Roberts; C, Underwood and Underwood; D, Gendreau

Most domesticated cats belong to (or are closely related to) the breeds shown here: A, Manx; B, Siamese; C, Persian; and D, common

Exercise. Imagine that you had been given money to buy just the type of dog or cat you wanted. Which one should you select, and why? Prepare a good "sales talk" on your favorite dog or cat.

Sheep. Other animals were domesticated early in human history, some for their food value or for their hides, others as beasts of burden. Sheep, which belong to the first class, appear to have been first domesticated somewhere in the region of Syria or Palestine. The shepherd is a figure of the oldest Biblical history, and descriptions of the shearing of sheep come down to us from times as remote as three or four thousand years before Christ.

George McKerron & Sons Co.

This prize sheep was bred to order

Today the Shropshire is our most popular breed of sheep for meat production. As were many kinds of dogs, horses, and cattle, this variety of sheep was planned first and then bred to fit the plan. The American public demanded tender meat without strong flavor. The butchers wanted plenty of meat on the best cuts. The climate of this country demanded an animal born in the spring and ready for market in the fall.

Early in this century American breeders visited England and Scotland, for in those countries breeding of superior sheep has been carried on for centuries. But superior sheep for England and Scotland were not necessarily superior sheep for America. The British Isles have a mild winter season, for instance, and the British public likes strongly flavored mutton. But certain carefully selected animals were purchased and brought home.

One ewe, mated with an American ram, produced several exceptional offspring, close to the ideal that had been set. A grandson, named Senator Thickset (see above), received four first prizes at the International Livestock Show in 1929. He was the father of the first-prize pens of both ram and ewe lambs. He took similar honors in 1931 and 1932, and his offspring are also winning more than their share of blue ribbons. These sheep are one of the finest

N. Y. Zoological Society

The ancestors of these wild ponies of central Asia were probably the first horses to be tamed by man

examples of how the principles discussed in the last chapter in reference to plants have been applied to the breeding of a domesticated animal.

The Horse. Probably the first horse was tamed on the plains of central Asia, where wild horses still roam today. The illustration above shows a pair of such horses. You may say at this point, "Why, there are also wild horses on the Western Plains of the United States." That is true, but these wild horses have been wild for only a few generations. They are descendants of horses that were brought to this country by the Spaniards. Before the coming of the Spaniards there had been no horses on this continent for hundreds of thousands of years.

You have probably heard about a little horselike animal the size of a small terrier, known as Eohippus. Fossil bones of this creature are found in the soil of the Western Plains.

This little animal is believed by scientists to be a distant ancestor of the modern horse. It lived in North America long before there were any people there. In some manner unknown at present the descendants of Eohippus seem to have spread into other parts of the world.

Long after the day of Eohippus, about 2000 B.C., tribes of half-civilized people migrated into Asia Minor from the East. They rode on horses and packed their possessions on the backs of other horses. From then on horses were used throughout ancient and medieval civilizations. The Greeks used them and so did the Romans, and so did the knights of the Middle Ages. But the American Indian roamed the plains on foot. He had no horses to act as beasts of burden because, though these animals originated in America, they died out there and did not return until the Spaniards brought modern horses from Europe in the sixteenth century.

The modern horse is highly intelligent, more intelligent perhaps than all other animals except the great apes and the elephants. He is large enough and strong enough to carry heavy loads; a draft, or work, horse may weigh as much as a ton. Because his legs are adapted for running or walking long distances, a good horse can travel as much as fifty miles in a day.

Modern horses have been bred for several purposes and they differ accordingly. If you should see a draft horse, a race horse, and a saddle horse side by side, you would probably have little difficulty in telling them apart. The draft horse is much the heaviest. He has short legs, a broad chest, and a thick neck. His feet are large and broad. The Percheron, an especially fine breed of draft horse that was brought here from France, is shown on the opposite page. Race horses of course are bred for speed. They are among

U. S. D. A., Bureau of Animal Industry

These horses were bred for power

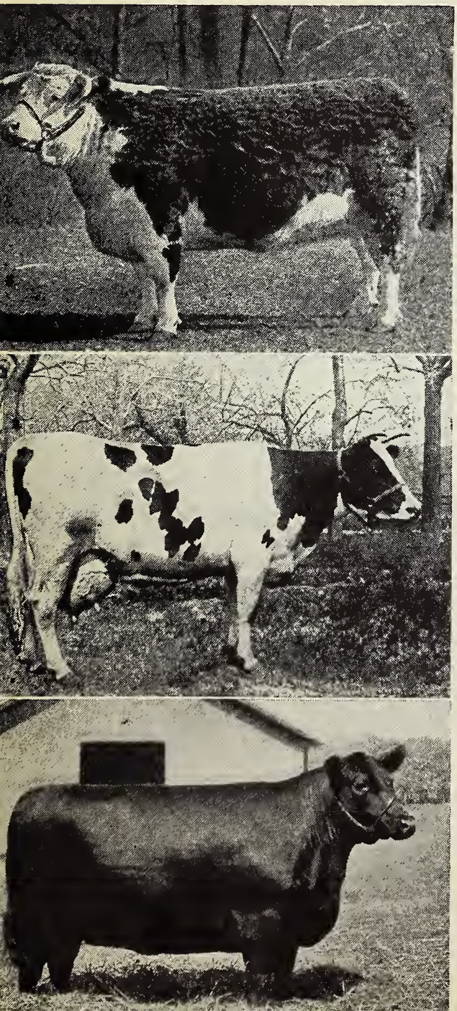
LIBRARY OF THE UNIVERSITY
OF ALBERTA

These horses were bred for speed

Galloway

the most beautiful creatures on earth. Who is not stirred by the sight of such horses as are pictured on page 51?

The saddle horse has come into its own in recent years in this country, owing to the increased interest in horseback riding. Many "carriage horses" and "coach horses," whose usefulness vanished with the coming of the low-priced automobile, have been put to work again as saddle horses. Thus even in the Machine Age there is place for the horse, aristocrat of the domesticated animals.



The heavy-set Hereford and Angus cattle (above and below) were bred for beef. The large-uddered Holstein cow (middle) was bred for milk

Exercise. Prepare a report for your class on "The History of the Horse." The American Museum of Natural History in New York has an interesting guide pamphlet on this subject by Matthew and Chubb. Other accounts may be found in textbooks of historical geology.

Cattle. Cattle are typical domesticated animals. To be sure, you can turn young stock out to pasture for a few weeks in summer and let them take care of themselves, but full-grown milk cows need more hay and grain than they can ordinarily get for themselves. The best beef cattle are never turned out to pasture at all.

Look at the cattle pictured at the left. These are obviously far from wild animals. The Angus and the Hereford are much too heavy for their own good. They can neither run fast nor fight, and are good only for beef. The Holstein cow produces enough milk for half a dozen calves. These and many other varieties of cattle have been developed by man to fit definite needs.

A superior herd of milk cattle is likely to be made up of Jerseys or Holsteins, although Guernseys and Ayrshires are also good breeds for this purpose. A cow produces her first calf when she is between two and three years old. Normally she gives birth to one calf a year, though occasionally to twins. The calf uses its mother's milk for about six weeks. Ordinarily even during this time the calf does not use all the milk, and what is left is used by human beings. After six weeks all the cow's milk may be used to meet human needs.

A cow may give milk for from six to eight months or longer, as much as twenty quarts a day when the calf is first taken from her. One Jersey cow gave 10,627 pounds of milk (more than 1300 gallons) during a single year, while a certain Holstein gave 13,986 pounds of milk during the same period. The Jersey, however, gave 521 pounds of butterfat in the form of cream, while the Holstein gave only 486 pounds. Profit on these two cows for one year was more than $200 each. These were not record-breakers, but simply good cows in a good herd. Good cows, on the average, produce over 300 pounds of butterfat in a year. A Shorthorn holds the record in butterfat production for all breeds, by producing in one year 32,522 pounds of milk (about 4000 gallons)! This milk contained 1614 pounds of butterfat.

Two types of cattle raised exclusively for beef are the Aberdeen Angus and the Hereford. These breeds give comparatively little milk, but make splendid meat. An Aberdeen Angus calf may weigh as much as half a ton by the time it is one year old. It is fed on grain and hay until it is fat enough to be killed.

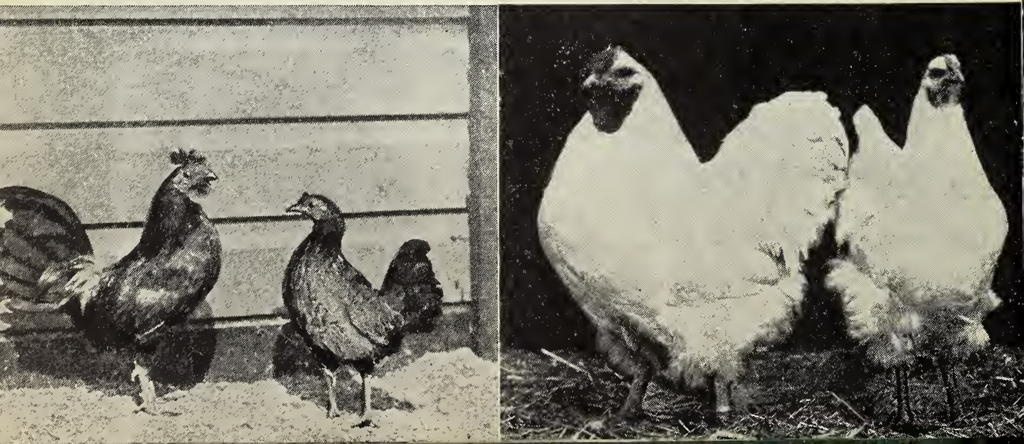
Exercise. Make a study of a prize cow. See how far back you can trace its ancestry. Pictures or diagrams, if you can obtain them, would help to make your story clearer. If there is a kennel club or a cattle-breeders' association in your locality, they can help you.

The Domestic Fowl. One more domesticated animal is sufficiently important to deserve our brief attention. We refer to the domestic fowl, or chicken, whose ancestors came from the bamboo jungles of India or possibly Malaysia. The modern fowl has been bred for its flesh, its eggs, and its feathers. Some of the results of domestication and careful breeding may be seen by comparing the red jungle fowl with the White Wyandotte, as shown below. Can you see one reason why the wild jungle fowl is a poor source of food when compared with the White Wyandotte?

Exercise. Make a special study of the red jungle fowl of India, using Beebe's beautifully illustrated book, *Pheasants.*

One especially important man-produced improvement among the characteristics of the modern fowl is in the time

Through selective breeding the ancestors of the small, lean, jungle fowl on the left gave rise to the large fleshy chickens on the right



at which pullets (young hens) begin to lay. Some of the best now lay their first eggs when only five or six months old. This means that, since the chick was hatched in the spring, the hen will be laying during the winter months when eggs are less plentiful and therefore more expensive. It also means a shorter period before the hen begins to pay for herself.

Some of the most popular breeds of hens in North America are the Plymouth Rock, the Rhode Island Red, the White Wyandotte, and the White Leghorn. Whiteness as inherited in some varieties is a dominant Mendelian characteristic, while in others it is recessive. Rose or double combs, as opposed to single combs, are always dominant. Early maturity appears also to be a dominant characteristic.

Let us consider a flock of Rhode Island Red hens. All of course are red. A White Leghorn rooster is added to the flock. Next season when the chickens hatch, every single chick is white! But you must not expect that these white chickens when mature will themselves produce all white chicks. If a rooster from this hatch is kept with the hens from the same hatch, you will have some red chicks again next season, this time in the proportion of three white ones to one red one. But if these second-generation red ones are kept by themselves, they will never produce a single white chick!

One third of the white chickens of the second generation will produce only white chicks, but the descendants of the other white ones will again appear in the proportion of one red to three whites. These results, as you probably have already recognized, are exactly what you found in the case of the tall and dwarf peas which you studied in the last chapter. It shows that animals, like plants, are governed by Mendelian principles.

Exercise. Make a chart for the crossbreeding of a White Leghorn rooster and a Rhode Island Red hen. Carry it to the third generation as in the diagram on page 29.

On the larger poultry farms eggs are hatched almost exclusively in incubators (see opposite page). This saves three weeks' time during which a hen might be laying, and it makes possible a hatch of two or three hundred or more eggs at one time. Incubators must be tended carefully in order to provide a free movement of air and a proper temperature. This temperature must be that of the hen's body, which is about 120° F., and it must be kept even during the entire three weeks of incubation.

THE BREEDING AND CARE OF DOMESTIC ANIMALS

How the Animal-Breeder Works. We have already seen that many of the same principles of breeding can be used in the improvement of both animals and plants. As with the plant-breeder, it is the task of the animal-breeder to select those individuals which have the characteristics he wishes; and also to keep his eye open for possible "sports," or freaks, which may turn up quite unexpectedly with the good qualities he desired. These "sports" often breed true, and through them new colors or new forms may be developed.

The animal-breeder can also, by crossbreeding, combine certain desirable characteristics possessed by different varieties of the same animal species. In rare cases he can cross two different species, as he does the horse and the donkey to obtain the mule. The mule, however, almost never has the power to reproduce. Every mule has a horse for a mother and a donkey for a father.

The practical breeder has long had certain rough principles which have served him as guides. He has known that some animal parents have a remarkable ability to produce offspring with the same desirable qualities. He has known also that many characteristics tend to skip a generation; that certain characteristics might not appear for a number of generations and then show up as "throwbacks." He has known that highly selected breeds sometimes tend to lose vigor, and that first-generation crosses of different breeds are often remarkably vigorous.

Today we know that there is a scientific explanation for all these crude rules of the practical breeder. Knowing this, we are often able to save much time and labor in securing the results we want. Very careful records, or *pedigrees*, show what happens in breeding over many generations. Modern pedigrees show the failures as well as the successes. The old way was to wait until a success occurred, then go back over the ancestry and try to explain it.

Incubators have replaced mother love on the modern poultry farm

Galloway

Exercise. Obtain the pedigree of some domesticated animal from a breeder or veterinary. Find out what information it contains and report on it to your class.

Breeding Animals to Order. It is scarcely too much to say that the modern breeder can make animal types to order. You will find it very profitable to visit animal shows whenever you can and see how perfectly certain ideal types of dogs, chickens, and horses have been thought out and described. The animals exhibited are judged by the closeness with which they approach these ideal types. Just as the sculptor in designing a statue shapes it toward an ideal of strength, grace, or movement which he has in his mind, so the animal-breeder shapes the forms of living flesh through the generations.

The gamecock, designed for speed and power in fighting, is as beautifully modeled as a French sword. Everything which interfered with the desired qualities has been eliminated. In contrast, the body of the little Leghorn hen looks like a basket to hold and produce just as many eggs as possible. And you will see a similar beauty and fitness of form if you compare the prize dairy cow, with her small body and tremendous udders, with the vast smooth body of the prize beef animal.

How Livestock Is Improved. Of course, the production of such perfect, or *pure-bred*, specimens is an expensive and difficult business. They cannot be used to stock the average farm, for they are too costly. They are used for breeding purposes, being crossed with the average animals found on the farm and thus improving the offspring. Such improved stock is known as *grade* or *high-grade*, to distinguish it from inferior, or *scrub*, stock.

There are many factors of his environment which the farmer cannot control, but he can at least be sure that his livestock is of superior type. One of the most practical measures for his benefit is the supplying of superior breeding stock. In many communities the yield of milk and butterfat has been greatly increased by the presence of a bull who could transmit the capacity for superior production to his offspring. Better egg production speedily results to the poultry farmer who buys well-bred chicks and removes the hens which do not earn their keep. Even the bee-keeper finds it profitable to buy superior queens and introduce them into his hives.

Exercise. Visit a modern poultry or dairy farm and find out what methods the farmer uses to improve his stock.

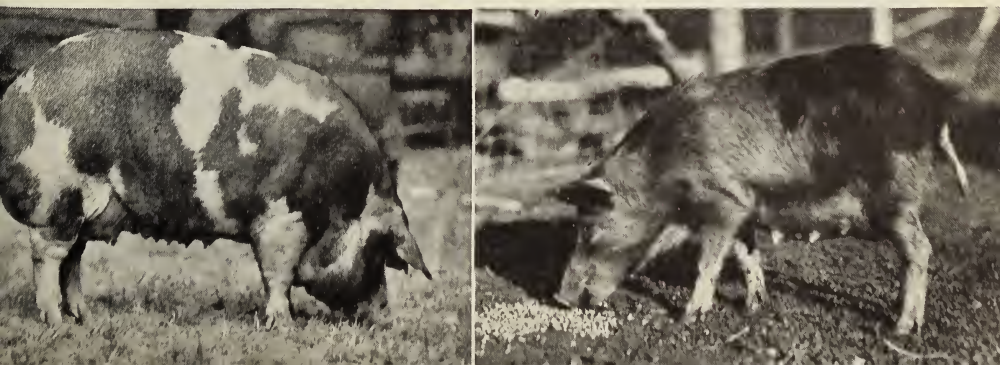
Animal Husbandry. The art of caring for domestic animals is known as animal husbandry. Today it is carried on scientifically, but we must not forget that men developed great skill in this art long before the days of modern science. In other words, good practices were followed long before the reasons why they were good were understood. With the aid of science, however, we not only understand many of these reasons, but we have also been able to make much improvement in the practices.

Need of Caring for Domesticated Animals. In earlier days domesticated animals were obliged to hunt for much of

You cannot make a silk purse out of a sow's ear,"

but you can make better sows out of poorer ones by careful breeding

U. S. D. A., Bureau of Animal Industry

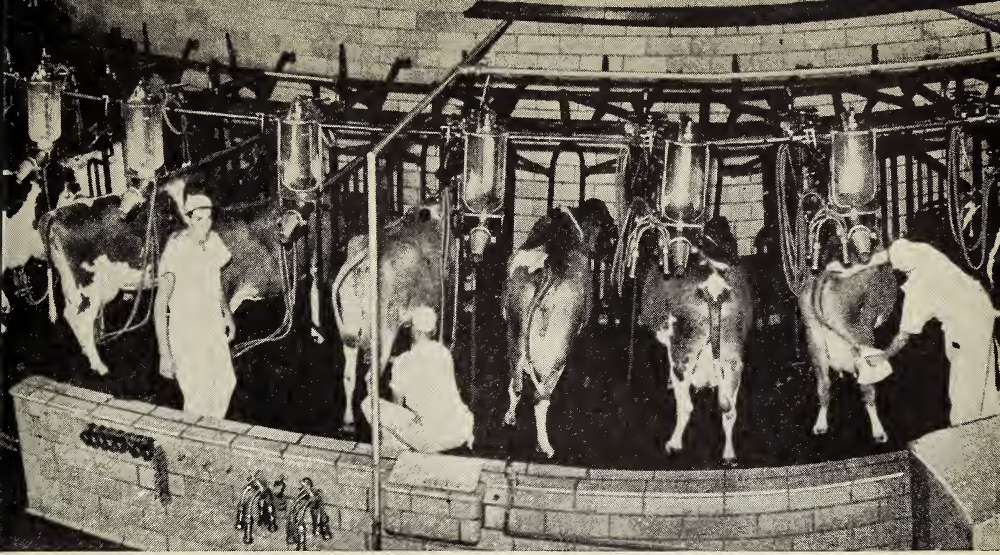


their own food. Even today in some regions where land is cheap and people are few, labor is saved by letting the domesticated animals shift pretty much for themselves. This practice, unfortunately, takes energy which the animals might better save and use in the production of meat, milk, or eggs. It also exposes the animals to the risk of injury or death. And while it saves the time that would otherwise be devoted to producing food for them, it requires the effort of rounding them up. Furthermore, animals that forage for themselves are not likely to be as tame as those that are constantly tended by their owner. They tend to return to the habits of their distant ancestors.

Not only is the amount of produce yielded by half-wild domesticated animals likely to be less than that which is yielded by carefully tended animals, but the quality may be inferior. Eggs from hens which have been feeding on

Modern animal-breeders measure livestock as carefully as dressmakers measure cloth

Life Magazine



Walker-Gordon Laboratory Co.

The modern dairyman has learned that care and cleanliness pay

grasshoppers or wild onions, for example, do not have a pleasant flavor. When cows eat wild turnips the milk is worthless. It is also important, if one wishes to control the breeding habits of domesticated animals, to keep them under close supervision. Otherwise they are likely to mate with inferior stock.

As people become more numerous in any given region, land there becomes more costly. It is then necessary to use it as wisely and economically as possible. To be sure, there are still great open stretches, including more than one third of the United States, which are better suited to the grazing of large herds of animals than to most other uses. But even here it is found that the animals thrive best if carefully tended.

Great flocks of sheep, often guarded by a lone man and his dog, are moved about over the Rocky Mountains so that they do not destroy the pasture and yet find as good feed as possible. And instead of the little, half-wild Mexican longhorn cattle which used to be grown in our Western states, we now have herds of the large, quiet, white-faced

Herefords. These animals move slowly, are easy to handle, and much of their food goes into the making of beef.

Feeding Livestock. Before cattle that have been feeding on the open range can be marketed for beef, they are very often brought in and given a special fattening diet of corn or cottonseed cake and hay. This diet increases not only the quantity but also the quality of their meat. Care is taken to keep them quiet so that they do not "burn up" their fat in useless exercise.

As in the case of human beings, all livestock require a suitably balanced diet with the right proportion of fats, carbohydrates, and proteins. Either in the food or along with it there must be enough of the essential minerals. Lime, for example, is needed for the formation of teeth, bone, milk, and eggshells. For the larger domesticated animals salt must be furnished in blocks, called "rock salt." In any large pasture you can see this salt, often put out near the watering-place of the cattle.

One of the important minerals for all animals is phosphate. There are many places where phosphate rocks are scarce, especially if the original topsoil has been washed away. In such places the farmer may find that his animals are unhealthy unless phosphate is added to their diet. In some places cattle and horses are fed on dried fish, for fishbones are rich in phosphate.

With many kinds of animals care must be taken not to feed them too much. With chickens, for example, it is an old rule to feed them only what they will eat up clean. Horses and cattle are often given regular feedings of grain and then allowed to eat as much hay or grass as they desire. Plenty of clean water is as necessary for our domesticated animals as it is for us. In fact, cleanliness of body

Luke Pasco

This dog has been trained to feed milk to orphan lambs.
When the bottle is emptied, the dog gets another bottle for another lamb

and surroundings is an important part of the care of animals. Animals also need sunlight and fresh air, along with protection from severe heat and extreme cold.

Training Domesticated Animals. Although few kinds of young animals are so helpless as a human baby, the owner generally finds it necessary to give them and their mothers some attention. In the case of sheep, for example, many ewes can be saved by proper shelter and care at lambing time. Because we use the milk of cows and goats which the animal produces to feed its young, the calf or kid must be taught to eat other food as soon as possible.

The "weaning" of a calf is an example of the training which all domesticated animals require. Its mother must become accustomed to being milked by human hands or a milking machine. The horse, on the other hand, must learn to be harnessed. The steer must learn to be yoked. Animals that work for man, like the shepherd dog, the horse, and the ox, must be trained with great skill. This is readily done by gentle and intelligent handling from the time the animal is very young.

Each animal, like each human being, is an individual, and not exactly like any other animal of the same kind. Skillful trainers know this, and it is one of the reasons why work with living animals is an interesting occupation. Men who control animals successfully must first be able to control themselves; they must know what they want the animal to do and then see that he does it. Punishment should not be severe, but it must be certain and immediate, so that the animal connects it with his disobedience. Reward should follow obedience promptly and certainly.

Exercise. Make a study of the proper feeding and training of one type of domesticated animal. Write a report on your findings, with recommendations on what to do as well as what not to do.

The Farm as a Factory. The care of domesticated animals, like medicine or business, is more and more coming to be a matter for the specialist. The general farmer still has his horses, cows, pigs, sheep, poultry, and bees. But as the demand for higher quality increases and the cost of production with it, we find more men who give all their attention to dairying or beef production; to fine wool-growing, eggs, market poultry, or some other specialty.

Thus the farm, like the modern factory, can be especially equipped and run for just one purpose. On such specialized farms we even find foxes grown for their fur, carp grown in ponds for the city markets, and quail or pheasants grown for bird preserves. When this is done, the farm really becomes a factory for animals, rather than a home for the farmer. It is more efficient than the old way, sometimes more profitable, certainly more scientific.

Exercise. If there is a specialized farm in your neighborhood, visit it and observe all the ways in which efficiency has been increased through the use of modern scientific methods.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Man did not begin to domesticate animals until long after he had learned to cultivate plants.

2. The Eskimo is one of the few modern peoples that have remained wholly in the hunting stage of human development.

3. The bison is a truly domesticated animal because it breeds in captivity.

4. There are one hundred and four different breeds of dogs, and all have been developed within the last two hundred years.

5. The finest sheep in the world originated in North America and were later exported to England and Scotland, where mutton is a favorite food.

6. The modern horse originated in America in the very regions where its little ancestor, Eohippus, once roamed many aeons ago.

7. The Machine Age has done away with the use of horses.

8. It is not unusual for a Hereford cow to produce 10,000 pounds of milk in a single year.

9. The breeding of chickens is less scientific than the breeding of other domesticated animals because they do not follow Mendelian principles.

10. The mule is one of the most successful animal hybrids because it always breeds true.

11. The modern science of animal-breeding has improved very little on the art of the old-fashioned breeder.

12. "High grade" is a term applied to domesticated animals which are used exclusively for breeding purposes.

13. Domesticated animals that must hunt for their own food are healthier and better producers than animals that receive more care.

14. The best modern domesticated animals do not have to be trained because instinct makes them behave as man desires them to behave.

Questions for Discussion

1. How did the domestication of animals make it possible for man to establish more permanent homes?

2. Could domesticated animals live if they were suddenly deprived of man's care and protection? Can you think of any that might go back to their wild state?

Things to Do

1. Keep a scrapbook on prize-winning domesticated animals. Nearly every day the newspapers carry accounts and often pictures of such animals, with interesting notes on how they were bred and trained.

2. If you or any of your friends have a new litter of kittens or puppies at home, study them to find individual characteristics which have been inherited from their father

and their mother. Consider such questions as: "Do some resemble one parent, and others resemble the other parent?" "Are any of them entirely unlike either parent?" See what other interesting things you can find out about them.

3. Make a study of the common breeds of cattle. Find out the special characteristics of each breed and how each breed was developed.

4. We speak of the value of fur which is now produced by domesticated fur-bearing animals. See if you can find out about the types of animals most often used for this purpose, how they are domesticated, and how the value of their fur compares with that of animals trapped wild.

CHAPTER THREE

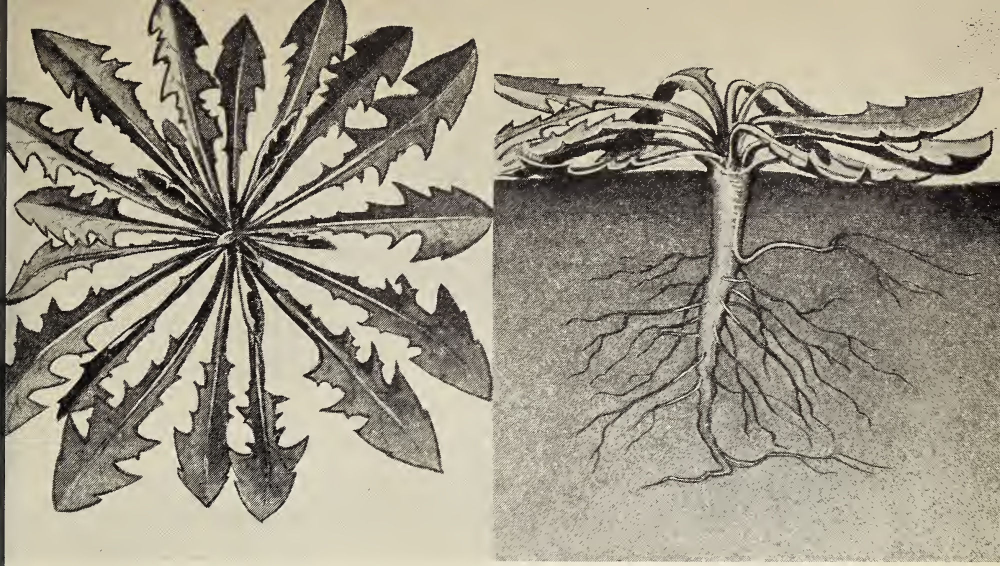
How Do We Protect Our Domesticated Plants and Animals?

THE WAR AGAINST WEEDS

Why Domesticated Creatures Must Be Protected. It is not enough for man to select and breed such plants and animals as can serve his needs. He must also protect them against their enemies. The earth is full of living creatures all struggling for a place in the sun. Ordinarily, only the most vigorous survive.

Domesticated plants and animals have been coddled by man. Most of them would die if they had to compete with wild plants and animals which have grown strong through shifting for themselves. That is why man must fight an endless war against the enemies of his pets. That is why the story of our domesticated creatures would not be complete without a chapter on how we protect them from destruction.

What Weeds Are. One of the greatest enemies of domesticated plants is weeds. *A weed is merely any plant that grows where we do not want it to grow.* It is generally a wild plant that forces its way into our gardens and croplands, crowding and robbing the plants that we do want to grow there. Weeds damage cultivated plants by taking from the soil the nitrogen and other chemical elements which are necessary for plant growth. They are damaging also because of the water they take from the soil.



he dandelion thrives because the wheel-like cluster of its leaves (left) insures the reatest possible amount of sunlight, and because its sturdy taproot (right) can weather every hardship

Why Weeds Are So Hardy. Consider the dandelion pictured above, a typical and familiar weed. It is summer, and the dandelion plants in your lawn have been blossoming since early April. You have mowed the lawn many times, but the little yellow blooms continue to appear down tight to the ground, out of reach of the mower's blades. Many others have bloomed and gone to seed, and their white tops have blown away. But they will turn up again next spring, never fear, as a new crop of weeds.

A count once showed that a single dandelion plant may produce as many as three hundred and fifty-three blossoms in a single season. Do your roses, peonies, or even your petunias ever do as well as that? Do their seeds ever drift away on the wind to produce new plants next season? In most cases the seeds of garden flowers do not even develop! In the few cases where they do develop they generally do no better than sift into the ground about the parent plant.

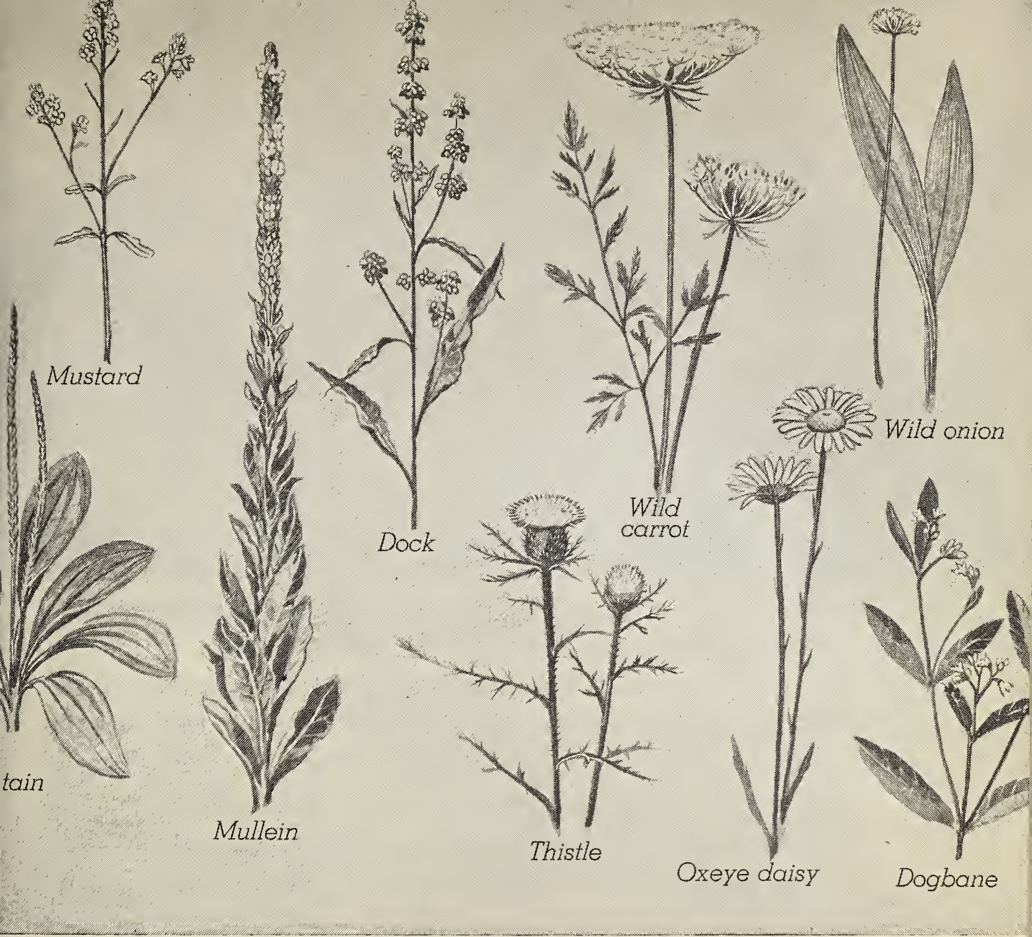
Notice the leaves of the dandelion shown above. See how they are arranged in a little *rosette*, or wheel-like cluster. There may be twenty or more of them, yet each one finds a place in the sun. Each one is a food factory in which carbohydrates are made during every sunlit hour. And notice how they are arranged to spread over the grass which may lie beneath them. What chance has grass of living below such a thick green mat?

Now suppose you try to pull up a dandelion by its roots. "Impossible," you say; you have tried it. Well, then, dig one out with a trowel. Note the length of the thick *taproot*, as shown on page 69. Note its strength. Compare this root with the roots of a petunia, a geranium, or any other small garden plant. Do you see why the dandelion continues to live, even when the whole top is cut off? It lives in its sturdy roots through every hardship. Through its sturdy roots it can even live through the winter and produce new blooms next spring.

Exercise. Carefully examine your own lawn or garden for weeds. Plants with rosettes that spread in the sunshine and with large roots that cling tightly to the soil are apt to be weeds. How many different kinds can you find?

Let us look about the lawn for other weeds. Here, for example, are plantains, both the wide-leafed and narrow-leafed varieties. Plantains, like dandelions, have tough roots, and many of them. Mustard, mullein, dock thistle, wild carrot, and many other weeds will doubtless reward our search. Such weeds as are shown on the opposite page will find their way into even the best-kept lawn.

Give a thought to the seeds of these plants. Are there many of them? Are they easily spread from place to place? Are they hardy? One scientist tells of some work in counting weed seeds. A single average-sized pusley plant pro-



How many of these weeds do you know?

duced 69,000 seeds. A rosette of Queen Anne's lace produced 50,000, and a mustard plant produced 1,500,000! He tells of further observations on weed seeds that lived in the ground without sprouting for as long as thirty years, and then sprouted when conditions became more favorable.

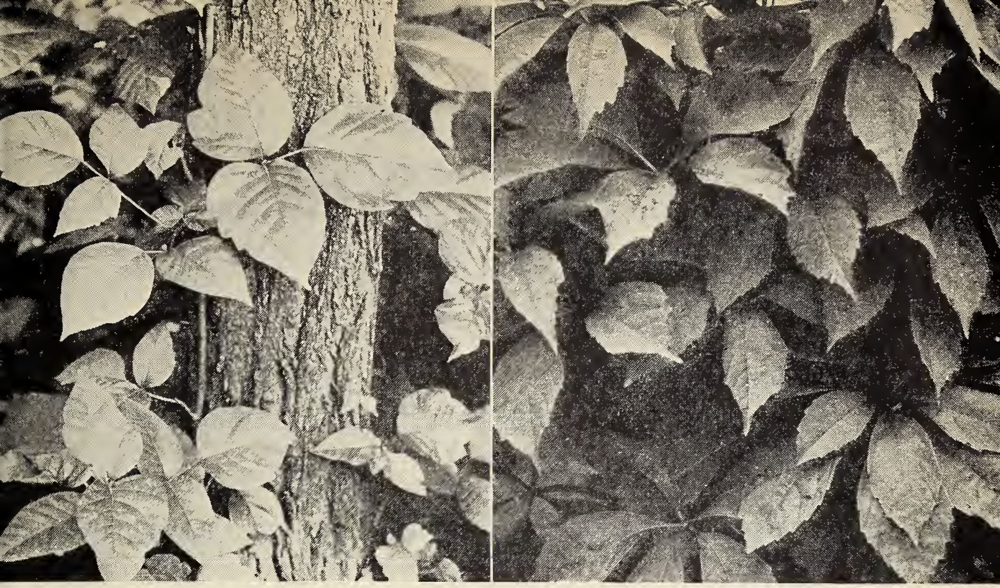
Pest Plants from Abroad. There is still another important reason why many weeds are so hardy. A plant in its native environment is likely to have many natural enemies. There are insects, fungus growths, birds that eat the seeds, and other things which prevent it from spreading. Some of the most objectionable weeds, on the other hand, are *not* native. For one reason or another they have been brought to where they are from somewhere else. With few of their old enemies in the new environment to stop them, they thrive and spread.

Dandelions, daisies, sorrel, pusley, wild onion, pigweed, mustard, plantain, mullein, dock, and thistle are some of the weeds that have been imported into this country from abroad. At the time they were brought in some of them were considered useful as medicine or spring tonics, some as "garden greens," and a few as decorative additions to the flower garden. All, however, have become pests which we should be glad to get rid of if we only could.

A number of plants, imported recently, are rapidly becoming pests. During the World War of 1914–1918 the English foxglove, or digitalis, was raised in gardens in this country. It has beautiful tall spikes of blue blossoms, and is also useful as a medicine for the heart. In several localities, however, it has proved much too well adapted to its

The water hyacinth is a beautiful plant, but it chokes the waterways of Florida

Sawders



Hugh Spencer

oison ivy (left) and Virginia creeper (right) are relatives, but their natures are very different

new environment. It has escaped into cultivated fields, where it is becoming a troublesome weed.

You have probably read about the red poppies that grow in the fields of Flanders in Belgium. They have become an emblem of the World War veterans. These beautiful flowers, a nuisance in Flanders wheat fields, have recently been brought into America with imported wheat seed. Will they become a nuisance here?

Not all pest plants are immigrants from abroad. Thick in the ponds and streams of Florida is the beautiful water hyacinth shown in the photograph on the opposite page. You who live in Northern cities may pay a quarter apiece or even more for these plants when you buy them for your aquarium. But Floridians would be very glad to get rid of all the "lilac devils," as they call them, because they choke up the rivers and lakes.

Poisonous Weeds. Though the chief objection to weeds is that they take the place of other plants of greater value, there are other reasons for disliking them. Take, for example, the case of the wild onion which may grow in wheat fields. Just a very few onion seeds ground up with the wheat will make flour unfit for use. A little wild onion in a cow's diet results in milk that smells like garlic. Daisies and dandelions dried in hay and fed to cows produce bitter milk. Other weeds in the fields are poisonous or even deadly to cattle, sheep, and horses. Among these are low laurel, water hemlock, dogbane, nightshade, pokeweed, and locoweed. One of these poisonous weeds is shown on page 71.

Poison ivy, poison sumac, and poison "oak" are poisonous to the touch as well as to the taste and may cause severe skin infections in man. If you do not already know these plants, you should learn to recognize them and to keep at a safe distance. Their poison is in the form of an oil which comes from the leaves and stems. This oil may turn to vapor, and persons especially susceptible may be poisoned as they pass along a road where the plants are being burned or mowed. On page 73 are pictures of poison ivy and its harmless relative, the Virginia creeper.

Two other weeds, giant ragweed and lesser ragweed, or wormwood, are believed to be among the chief causes of hay fever. The pollen from the flowers of these plants is carried by the wind and is extremely irritating to the mucous membranes in the eyes, nose, and throat of many people. Ragweed is shown

The ragweed plant is one of the world's greatest producers of sniffles and tears

Hugh Spencer

on the opposite page. You will be doing a real public service if you will co-operate in ridding your community of this pest.

Exercises. Find out what steps are recommended for fighting ragweed. What is being done in your community? What could be done?

Are there any poisonous weeds in your neighborhood? If so, see what measures have been taken to do away with them.

Control of Weeds. By understanding the nature and habits of our worst weeds we may be able to get rid of them; without this knowledge our war against them is bound to fail. Let us take dandelions again as an illustration. You go out on your lawn to dig them up. You should do this very early in the spring before the first seeds have ripened and blown away. You should be sure that you are using a tool which reaches the roots; for, if not, the roots will soon sprout again. And after you have dug them up, you should be sure to carry them away and destroy them. If you don't, they may take root and grow again.

These boys are waging—and winning—their war against weeds

U. S. Department of Agriculture

If there are so many plants that you cannot dig them all, a good method is to stab each rosette in the middle with a sharp stick dipped in carbolic or sulfuric acid. These chemicals are strong enough to kill even dandelions. Other kinds of rosettes in your lawn may be dug up or poisoned in the same way. But if the lawn is in very bad condition, it should be dug up, rolled, and reseeded. So far as possible, the grass seed should be free from weed seeds. Unfortunately, most grass seed contains weed seeds. Even in good-quality seed sold by reliable companies, as many as sixty thousand weed seeds per pound have been counted.

Exercise. Spread grass seed on a glass plate and with a hand lens search for seeds that are not grass seeds. How do you think they got there?

As for keeping the weeds out of a garden, there seems to be only one way. Just keep on pulling them up and hoeing them out. It is especially important, of course, to get rid of them before they are old enough to flower, so that no seeds may be formed. It is also important that they be placed where there is no possible chance of their rooting again. For this reason it is better to weed a garden during hot, dry weather than when the soil is wet. Do you see why?

When a farmer's hayfield becomes badly invaded by weeds, he has little choice except to mow the land early before seeds can form and then to plow the entire area. It should then be cultivated for one or two seasons, after which grass may safely be planted again. If the land is well fertilized and good seed is sown, the grass will get a start before the weeds do.

Grass needs soil which is acid and rich in phosphates, potash, and nitrates. Weeds, on the other hand, grow best in an alkaline soil. An excellent lawn fertilizer used according to directions is ammonium sulfate. This chemical is slightly acid. Being acid, it encourages grass while it discourages the growth of most weeds.

Exercise. Make a study of the ways in which ten common weeds of your community are spread, and draw up a plan of the best ways of controlling them. A nurseryman or farmer can give you practical help with this exercise.

THE WAR AGAINST INSECTS

Man's Rivals in the Living World. Unfortunately, most of the plant materials which man finds good to eat are quite as tasty to other living creatures. Even wood, straw, and cotton, which man cannot eat, contain materials which can serve as food for certain animals and plants. Rabbits may destroy carrots and cabbages or nibble the bark of young apple trees. Crows may dig up sprouting corn, and even our domestic animals must be fenced away from growing crops. If we stop to think about it, however, we realize that man's worst rivals among the animals are the insects. The United States alone spends a large fortune each year to fight insect pests, yet the destruction caused by insects costs an even larger fortune.

Exercise. Talk to a farmer in your vicinity and find out what animals are the chief enemies of his crops. How many of these are insects? Which ones do the greatest damage and are the most difficult to control?

Why Insects Are a Menace. Why are insects such serious rivals of man? The answer lies largely in their unimaginable abundance. One female insect may lay many thousands of eggs, and the young insects are usually hungry feeders.

Life Magazine

These students at the University of Wisconsin are studying
man's chief rival in the living worl

Again, there are more than half a million known kinds of insects, each with its own peculiar feeding habits. There is hardly a substance suitable for food which does not have one or more insects devoted to eating it. Worse than that, there may be insects which attack any given plant at every stage in its growth. Some feed upon the seeds, others upon the young plant, others upon various parts of the mature plant, and still others upon the ripened fruit.

Though certain insects such as the silkworm and the honeybee are helpful to man, many others are public enemies. Grasshoppers, European corn-borers, Japanese beetles, Colorado potato beetles, cotton-boll weevils, Mexican bean beetles, chinch bugs, houseflies, mosquitoes, gypsy moths, tent caterpillars, measuring worms, cockroaches, and ants have all caused a great deal of trouble. And new insect pests are continually making their appearance.

All these harmful insects have habits we do not like. They eat the leaves or fruit of our trees, they destroy our garden vegetables, or they live in filth and carry disease. According to L. O. Howard, one of our leading students of insects, "Insects are man's chief rivals for the possession of the earth. They are damaging us more today than at any time since civilization began." Most of the insects that are causing serious trouble today (like many of the troublesome weeds) have been brought into the

Official inspection of baggage helps to check the spread of insect pests

Lange from Farm Security Administration

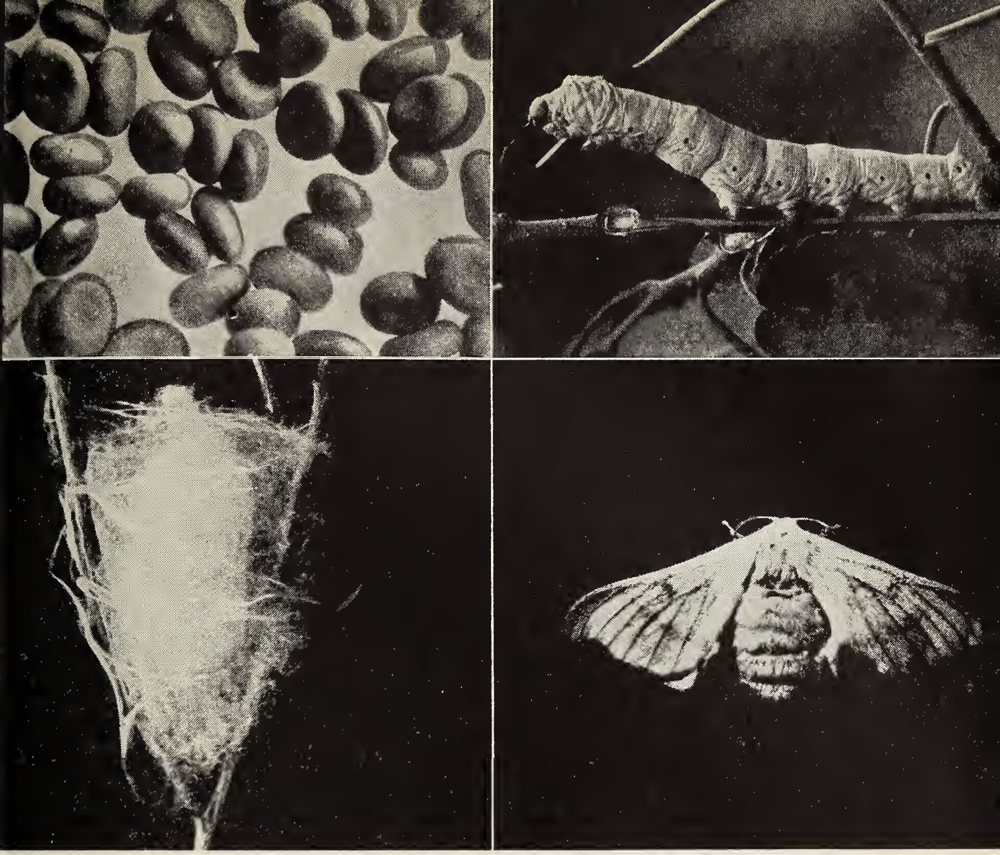
country, usually by accident, from abroad. Without their natural enemies, they thrive and spread.

What an Insect Is. Before we study the damage that harmful insects do, let us see exactly what an insect is. *An insect may be defined as a six-legged animal possessing a jointed body and a hard outer skeleton.* Most insects are small in comparison with most other animal types. Nearly all these creatures pass through four different stages in their life history, beginning with an egg and ending with an adult. During at least one stage they are generally tremendous eaters. Since many of them live upon plants that we need for purposes of our own, we class them as pests or nuisances. A few, as we have seen, have characteristics that make them useful, and the silkworm is one of these.

Let us study the silkworm, which is really not a worm but the offspring of a winged insect. Each silkworm hatches from an egg, and at the start is scarcely larger than this letter *s*. It is one of about a hundred *caterpillars*, or *larvae* (singular, *larva*), that are hatched from the eggs of one mother moth. The eggs are laid upon the leaves of a mulberry tree, and as soon as they hatch the caterpillars begin to feed upon the mulberry leaves. Each caterpillar eats several times its own weight each day.

Within a few days the hard outer covering of the tiny creature becomes too small for it. The caterpillar then crawls out, leaving its skeleton, or "skin," behind. It has another skin underneath, however, which hardens as soon as it is exposed to the air. The caterpillar continues to eat until again it is too large for its skin. It sheds its skin four or five times. Between each of these shedding periods it eats until it can hold no more.

Finally, when the caterpillar is about an inch and a half

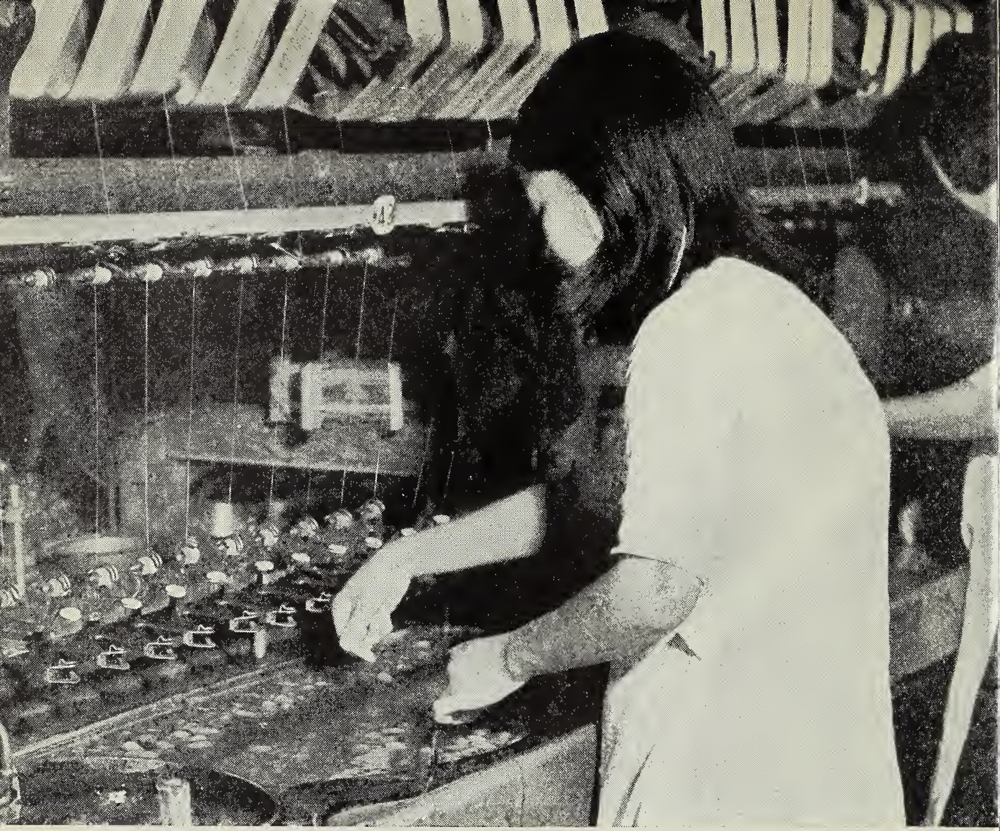


Upper right, L. W. Brownell

These are the four stages in the life of a silkworm

long and not quite so thick as a pencil, it stops eating. It now begins to spin from its mouth a fine cream-colored silk thread. This it wraps round and round its body until it is completely covered. The caterpillar inside the *cocoon*, as this silk covering is called, now sheds its last skin, which you may find inside the cocoon if you cut it open. The queer, quiet, brown mass that remains under the last caterpillar skin is called a *pupa* (plural, *pupae*). This pupa seems to have no legs, eyes, or mouth. It remains within the cocoon for about two weeks.

At the end of this time, if left undisturbed, the cocoon begins to move, to roll from side to side. From one end a wet insect appears. It has a large body and four small, soft,



Galloway

These girls are unwinding silkworm cocoons and collecting the thread

creamy wings. Clinging to a leaf or other object, the insect begins exercising its wings. By the end of half an hour they are dry and expanded. You recognize a rather pretty white moth, not so pretty, however, as our own larger native moths.

You have thus followed the silkworm through four stages in its life—the egg, the caterpillar (or larva), the pupa (in the cocoon), and the adult moth. These stages are shown in the illustration on page 81. If the adult moth is a female, she soon lays her eggs upon more mulberry leaves. The life history is then repeated.

All other moths and butterflies pass through these same four stages in their life histories, the caterpillars eating many times their own weight of their particular kind of food. Flies, beetles, bees, and wasps pass through similar stages. Insects that live through the four steps of egg, larva, pupa, and adult are said to have complete metamorphosis. *Metamorphosis* means "change of form."

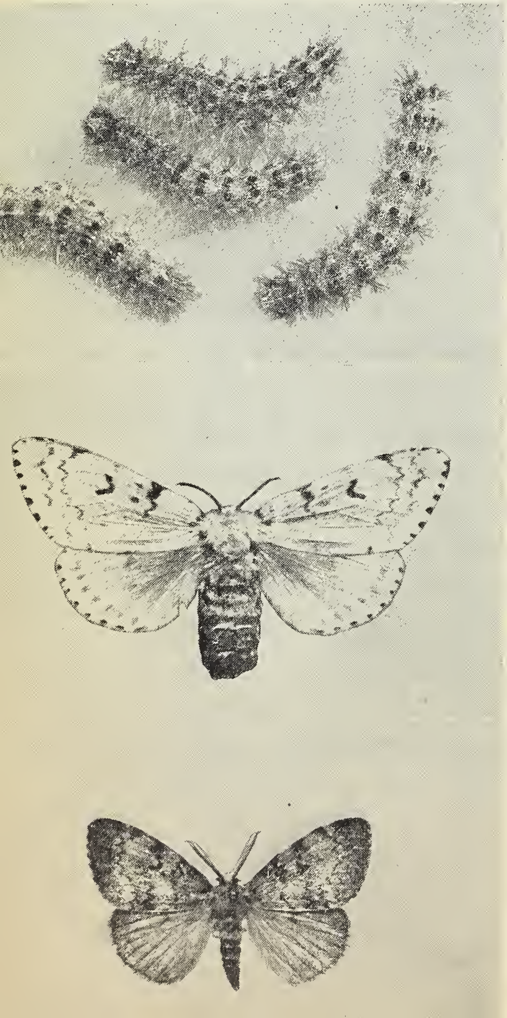
Exercise. Keep some insects in your classroom and watch them as they pass through the various stages in their life histories.

How Man Has Domesticated the Silkworm. Let us see how man interferes in the life of the silkworm. The silk cocoon is the source of silk thread and silk cloth. When it is spun into a cocoon by the caterpillar, the silk is all in one long thread; but after the moth has chewed its way out, the thread has been broken at every turn. Consequently, the time to collect the silk for use is before the moth comes out.

Accordingly, attendants who have cared carefully for the caterpillars, feeding them fresh mulberry leaves many times a day, collect the newly made cocoons and plunge them into boiling water. This kills the pupae, and the silk is unwound in a single thread as shown on the opposite page.

Although silkworms are not found wild today in any part of the world, it is certain that they had their origin somewhere in the Orient. They were introduced into Europe during the Middle Ages, and the silkworm industry became an important one in France. During the nineteenth century attempts were made to raise silkworms in several parts of the United States, and mulberry trees were planted in large numbers. But the industry did not flourish. Although both the mulberry trees and the worms seemed well adapted to the new environment, our people were unwilling to work for the small profits made by silkworm farmers in France and the Orient.

Story of the Gypsy Moth. Unfortunately, the silkworm has led indirectly to one of the greatest misfortunes in the history of man's war with the insect world. In 1869 in Medford, Massachusetts, a French astronomer was experimenting with silkworms as a hobby. He was trying to crossbreed silkworms with some small imported brown moths in order to produce a variety of silkworm which would be immune to certain common silkworm diseases. One day a box of eggs from the brown moths rested on a window sill. The window was open, and, according to the story, a sudden gust of wind scattered the eggs beyond recovery.

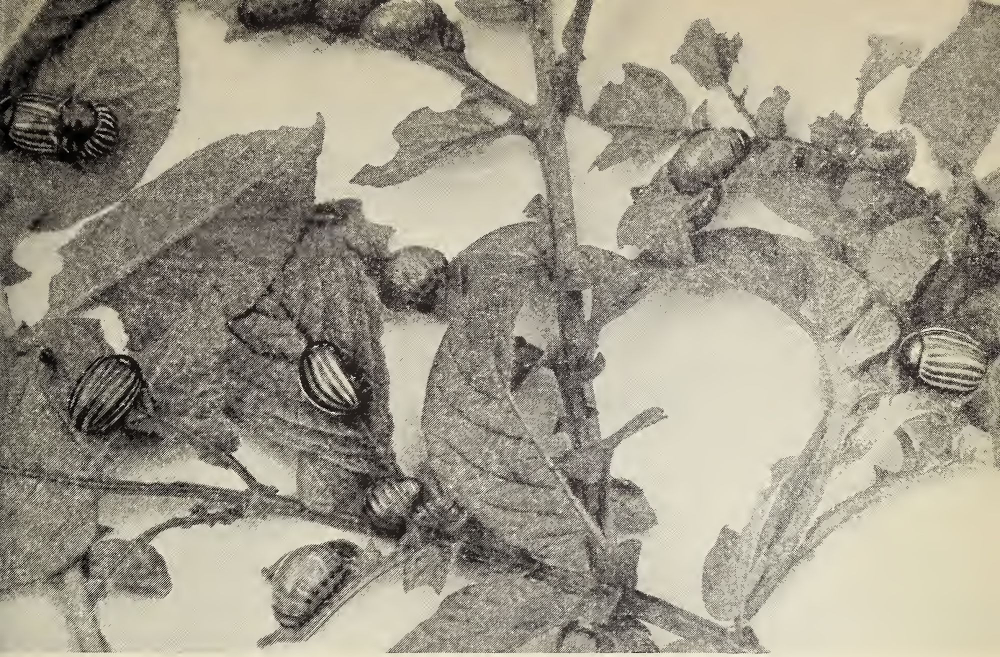


The caterpillars (top) of the gypsy moth (female in middle, male below) are deadly enemies of our native trees

U. S. D. A., Bureau of Entomology and Plant Quarantine

Nothing happened for a while. For nearly ten years there were not enough of these new insects in America to cause much damage. They passed unnoticed until suddenly vast quantities of caterpillars appeared which cleaned the trees of leaves for miles around. Within a dozen years they had spread throughout New England.

The scourge was especially bad because the caterpillars were not fussy in their choice of food. Nearly all trees were—and unfortunately still are—acceptable to them. The result is that seven hundred thousand dollars are spent each year from state and

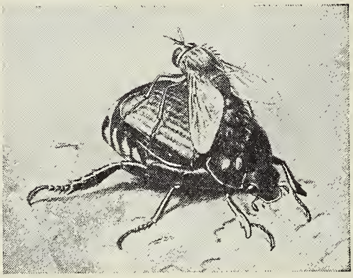


L. W. Brownell

e Colorado potato beetle (commonly known as "potato bug") is a familiar pest. Can you distinguish the larvae from the adults?

Federal funds to stop the advance of this one insect, the dreaded gypsy moth. Spraying the trees with poisons, introducing natural enemies to prey on the moths, and passing quarantine laws to prevent the transportation of uninspected nursery stock have all helped in the control. But the gypsy moth is still a serious enemy of our native trees. (See opposite page.)

The Colorado Potato Beetle. The Colorado potato beetle shown above once lived inoffensively and unnoticed upon the wild-potato vines of Colorado. Because at first there was never much food, there were never many beetles. But when white settlers arrived in Colorado with their cultivated potatoes, the beetles increased tremendously. They spread eastward, for there were potato fields all the way back to the Atlantic Ocean. They appeared in New England about 1875. Now in this country each year, thousands of farmer boys must do considerable work either "picking" or poisoning "potato bugs"! In spite of this work we share each potato harvest with these unwelcome guests.



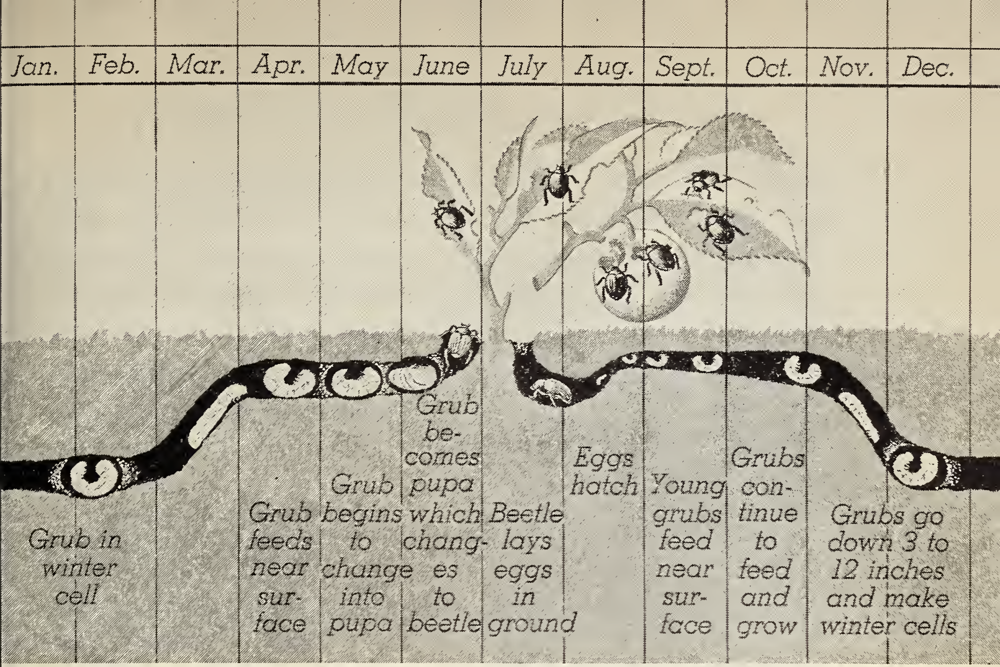
The fly is laying eggs on a Japanese beetle. When the eggs hatch, the larvae will feed on the beetle's flesh

The Japanese Beetle. More recently the Japanese beetle was introduced to America in a shipment of iris roots from Japan. It was discovered and identified by a government inspector in 1916 near Riverton, New Jersey. In 1917 Japanese beetles became numerous enough to be destructive. It was learned that the caterpillars feed upon grass roots and destroy lawns and fields, and that the adult beetles eat nearly any kind of plant.

Five years later the insects had spread across the Delaware River. They were serious pests in the Philadelphia area and were found on nearly all the farms in southern New Jersey. Their range covered a thousand square miles. Fifteen years later, in 1932, they had spread three hundred miles from the place of discovery.

The diagram on the opposite page shows clearly the life history of the Japanese beetle; the drawing above shows one of its most effective enemies. It is very possible that this beetle is now being held in check. At least half a dozen natural enemies have been introduced to fight it, and these appear to be successful. Special poisons, mixed with an oil which the beetles like, also seem to get results.

The Chinch Bug. The chinch bug shown in the inset of the photograph on page 88 is one of the most destructive


Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Grub in winter cell
Grub feeds near surface
Grub begins to change into pupa
Grub becomes pupa which changes to beetle
Beetle lays eggs in ground
Eggs hatch
Young grubs feed near surface
Grubs continue to feed and grow
Grubs go down 3 to 12 inches and make winter cells

his diagram shows why the Japanese beetle does much damage both above and below ground

of the insect pests in the sections of the United States where wheat and corn are grown. It lives in an immature form through that part of the season when wheat is growing, and then matures when the wheat is ripe. When wheat is ripe, corn is apt to be in a state of early growth. The chinch bugs feed upon the wheat until it ripens and then migrate to the fields of corn.

Advantage is taken of this fact in controlling these pests. The photograph on page 88 shows one of the measures that are taken. With the plow a trench is run entirely round the planted field. On one edge of the trench is a line of creosote which you may recognize as road-dressing tar. The crawling bugs will not cross this line of creosote. It serves as an effective blockade, preventing their entrance to the cornfield.

When these pests are bad, the trench along which the man is walking will contain an enormous number of chinch bugs. Since they will not cross the creosote, they will be moving in a direction parallel to the line. At intervals along the trench, as shown in the figure, holes are dug with a post-digger. The insects collect in these holes and are destroyed. As the insects reach the adult stage they develop wings, and then the creosote no longer serves as a protection. They may be extremely destructive to both wheat and corn, as well as to some other crops.

The European Corn-Borer. The European corn-borer, a moth that flies only by night, came into this country completely unsuspected. It ruined cornfields all over New England before farmers were aware of its presence. The caterpillar that does the damage lives not upon the leaves but inside the stem of the cornstalk, often moving upward into the cobs. Thus it leaves only a shell of a plant with sickly stalks and little or no corn, as shown on the opposite page. Government agencies are working to prevent the spread of the borer into the Western corn belt.

This man is making a trap for chinch bugs

U. S. D. A., Bureau of Entomology and Plant Quarantine

Exercise. Make a chart of the harmful insects in your locality, indicating their appearance, size, length of season, and methods of keeping them under control.

General Methods of Insect Control. It would be possible to go on for pages, telling how insect pests have spread and what damage they have done. But this section must come to an end, even though the war against insects must go on forever. Let us end this discussion, then, with three good general rules for the control of insect pests:

The European corn-borer did this

1. Keep your environment clean. Destroy rubbish in which insects may live through the winter.
2. If you discover a new pest, act promptly before it is too late. Find out what it is. Learn its habits. Then decide how best to destroy it.
3. Observe quarantine laws having to do with transportation of plants or soil that might contain insects. In a new section where it has no enemies, an insect may be a worse pest than in its native region.

THE WAR AGAINST DISEASE

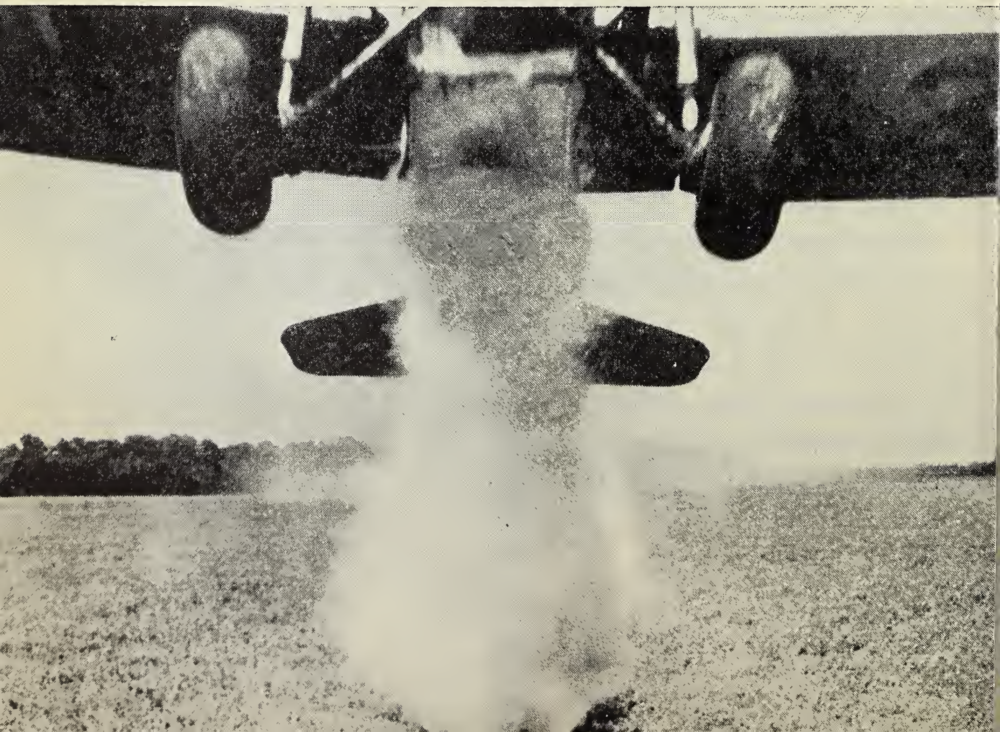
What Fungi Are. Among the chief enemies of domesticated plants are other plants known as *fungi* (singular, *fungus*). Fungi are flowerless plants that produce others of their kind by means of dustlike particles called *spores.* They contain none of the coloring matter (*chlorophyll*) which makes it possible for green plants to manufacture their own food. Consequently, the fungi must live upon food that is produced by other plants. Some of them live upon dead things and are known as *saprophytes*; among these are mushrooms, toadstools, and molds. Others live upon living things and are called *parasites*. Examples of parasites are the rusts that live upon larger living plants.

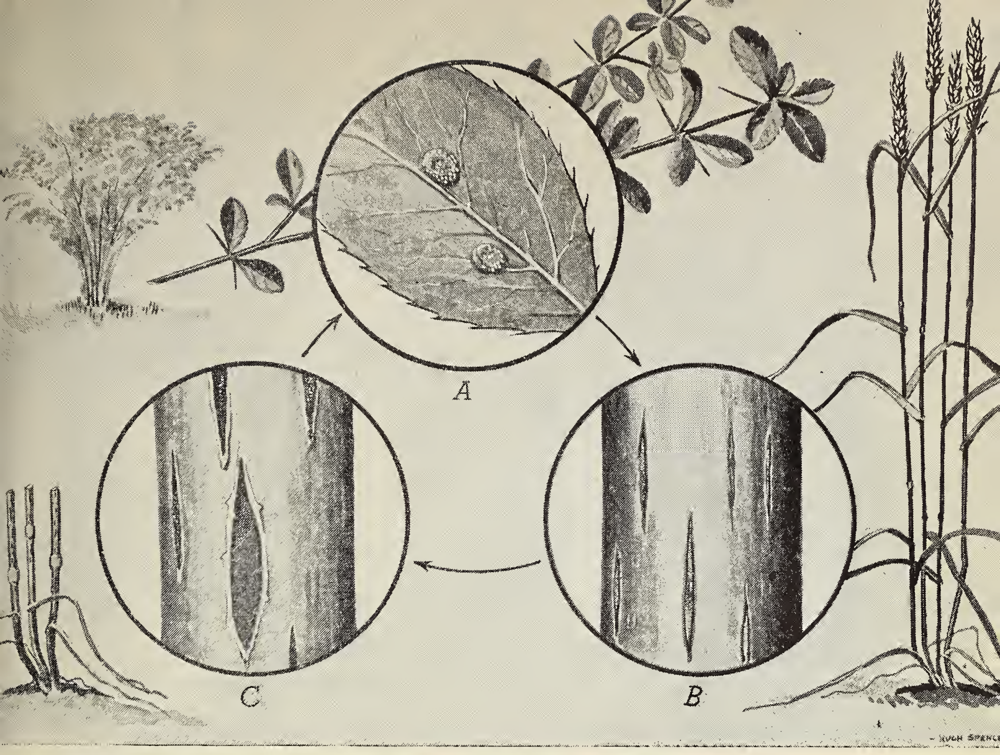
Life History of Wheat Rust. Rusts are fungi that reproduce by means of spores which look like iron rust. They pass through several different stages in their life history. The growth of wheat rust begins in the spring, when tiny cuplike organs filled with spores appear on the underside of the leaves of the common English barberry bushes. These spores, which grow only upon barberry bushes, are blown through the air until some of them fall upon wheat plants.

Soon reddish spores appear upon the wheat, and these may spread to other wheat plants. Later in the season black spores form on the wheat stalks, where they remain

Airplanes spraying planted fields are useful in the endless war against insects

Birds Eye Foods

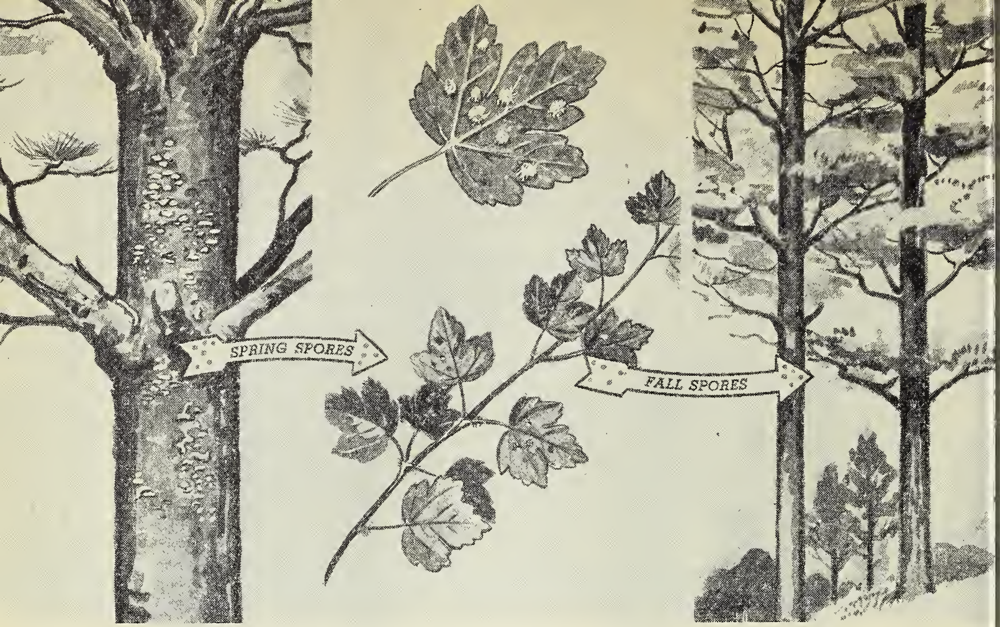




ed spores of wheat rust first appear in little cups on leaves of the English barberry A). Later they are blown to wheat plants and begin to feed on the green coloring atter (B). Finally they inflict ugly black wounds (C) which weaken or kill the wheat

quietly until early spring. At that time the spores are blown from the wheat to the barberries, and another life history begins. Because the rust feeds upon the green coloring matter of the wheat, it is very damaging. Study the diagram above which illustrates the life cycle of this plant.

How Wheat Rust May Be Controlled. There are two chief means of keeping wheat rust under control. One is to find wheat plants that can resist, or are immune to, the attacks of the rust. When such plants are found, new varieties can be developed from them in accordance with the laws discussed in Chapter One. Several varieties of wheat are raised today that are partially, but not wholly, able to resist rust.



The deadly white-pine blister is a fungus that lives for a time on currant and gooseberry bush

Another method of control is to do away with all the barberry bushes in the country. This does not include the Japanese barberry that is commonly used for hedges, but only the wild barberry originally introduced from Europe. For centuries there was a saying among European peasants that barberry bushes near a wheat field would spoil the wheat. Some people said it was only a superstition, but they were wrong. In this case a correct relationship was observed long before it was explained in a scientific manner.

Exercise. Read Chapters I and II of De Kruif's *Hunger Fighters*, which deal with the story of the fight for a rustproof wheat. The same story in equally interesting form is told in Cannon's *Red Rust*.

White-Pine Blister and Its Control. The white-pine blister is a fungus that attacks white pines. It never grows upon red or yellow pines. Just how it was introduced into this country no one knows, but it appears to have come from

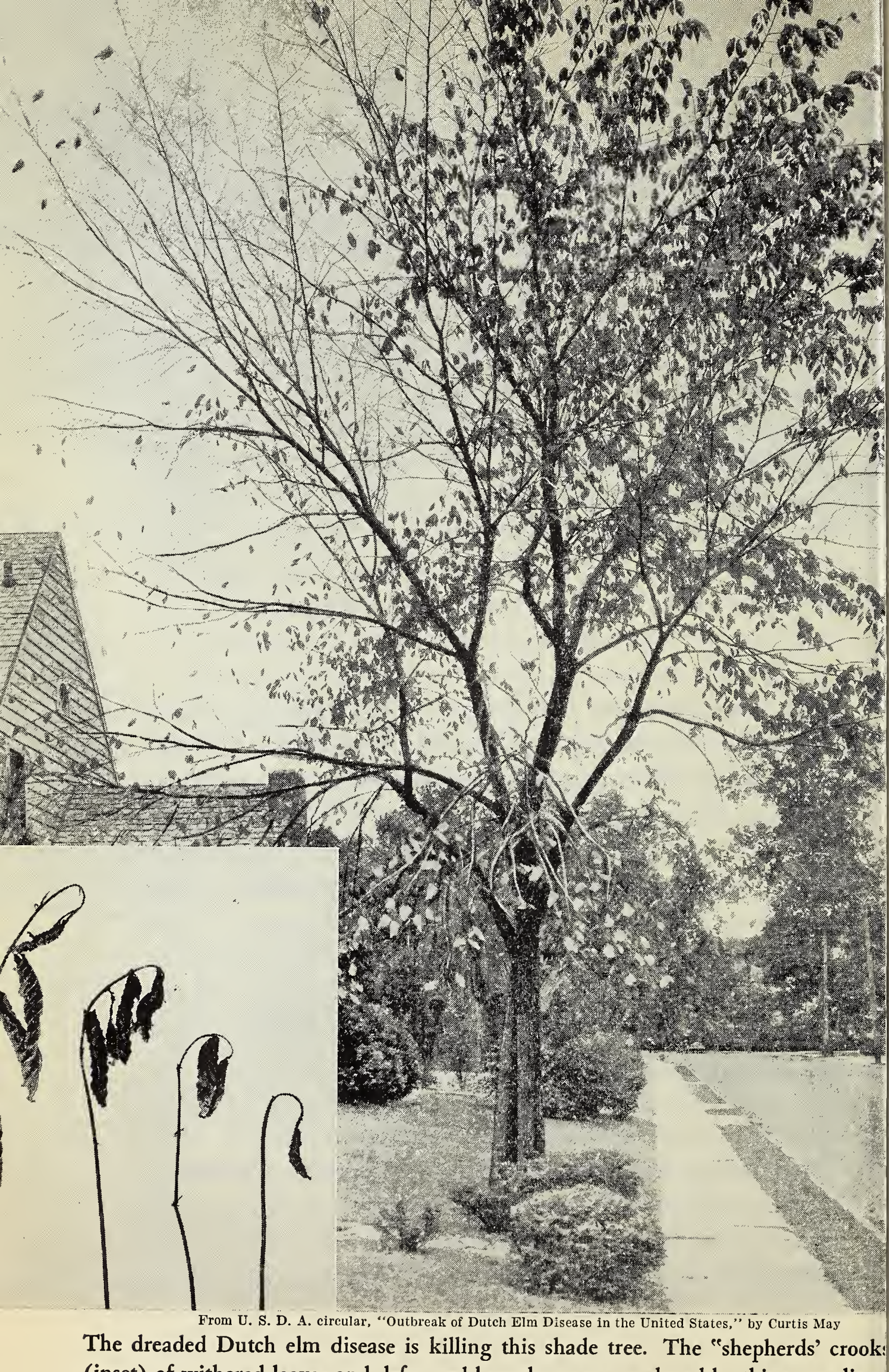
Europe early in the twentieth century. It spread rapidly through the pines of New England and New York, and experts of the Department of Agriculture began to study it.

They discovered that this fungus spends only part of its life upon the white pine. The rest of its life is spent upon currant or gooseberry bushes. It grows especially upon the English black currant. The life history is illustrated on the opposite page.

The best control in this case is to destroy all currant and gooseberry bushes, including wild ones that may be growing in the woods. This the state foresters proceeded to do through large sections of the country, much to the disgust of housewives who liked to make currant jelly and gooseberry tarts. But it was a question of losing the currants or losing the pine trees. Which do you think is more important?

The Dreaded Dutch Elm Disease. The Dutch elm disease is caused by a fungus which has only recently appeared upon elms in New Jersey and adjoining sections of New York and New England. This fungus grows just under the bark of the tree and may be identified as a thin brown streak. It is believed to have come to us from Asia, but by way of Holland, where it was noticed as long ago as 1919.

It is not known that this elm fungus lives upon any other plant, but experts are now fairly certain that it is carried from tree to tree by a hard-shelled brown beetle a little less than a quarter of an inch in length. It is called the European elm-bark beetle. The adult beetles carry spores upon their bodies from infected trees to healthy ones. Whether they have any closer connection with the disease is not yet known. The only way to prevent their rapid spread seems to be the burning of all trees that are found to be infected.



From U. S. D. A. circular, "Outbreak of Dutch Elm Disease in the United States," by Curtis May

The dreaded Dutch elm disease is killing this shade tree. The "shepherds' crook
(inset) of withered leaves and deformed branches were produced by this same disea

The Chestnut-Tree Blight. Scarcely a generation ago boys and girls who lived in the country spent many delightful autumn hours gathering chestnuts and eating them. Today boys and girls are likely to know only the horse chestnuts, which are not good to eat, or the huge Italian chestnuts which are sold at sidewalk stands in our large cities. Our native eating chestnuts have nearly vanished, the victims of a bark fungus brought into this country from northern China.

This little fungus, known as a blight, finds a foothold on the inner bark of the chestnut tree and sends out root-like threads in all directions. Upon the outer bark there soon appear little cups filled with spores. These spores stick to the feet of birds and insects and may be carried long distances. Other spores may be carried by the wind.

Unfortunately, no way has been discovered of stopping the progress of the chestnut-tree blight. Since 1904, when it was first discovered in a park in New York City, it has spread through nearly all the chestnut trees in the country. Even more recently, in the summer of 1934, there appeared upon the horse chestnuts in the Eastern states a blight of some sort that seems to be killing them too.

Exercise. Find out what activities directed toward the control of fungus diseases have been carried on in your community during the past five years.

How to Fight the Fungi. What we have said of insects is also true of fungus pests. To control them we must understand them. The task is often difficult and costly, because there are many kinds. But every stage in the life history of a harmful fungus requires suitable conditions, and it is sometimes possible to control these conditions.

Many kinds of fungi may be killed by poisons, especially by the salts of heavy metals such as copper. Some varieties of crop plants are more resistant to certain types of fungus disease than other varieties of the same species. One of the best ways of fighting the fungi, accordingly, is to breed plants that can do the fighting for themselves.

Diseases of Domesticated Animals. Domesticated animals as well as plants are subject to diseases. Most diseases in animals are caused by parasites, which grow on either the outside or the inside of the body. The most serious of these parasites are the microscopic plants which are known as bacteria. Domesticated animals are subject also to many different kinds of larger parasites, especially insects and worms.

There are many ways in which animals may become infected with parasites. They may come in contact with other animals already infected or with the discharges from their bodies. Diseases caused by parasites usually produce epidemics, the disease passing rapidly through all the domesticated animals of the neighborhood. Hog cholera is an example of this kind of disease. Tuberculosis of cattle, which makes their milk dangerous to people, is another disease that spreads rapidly. Herds from which milk is sold must be inspected regularly, to be sure that the cattle do not have this dread disease.

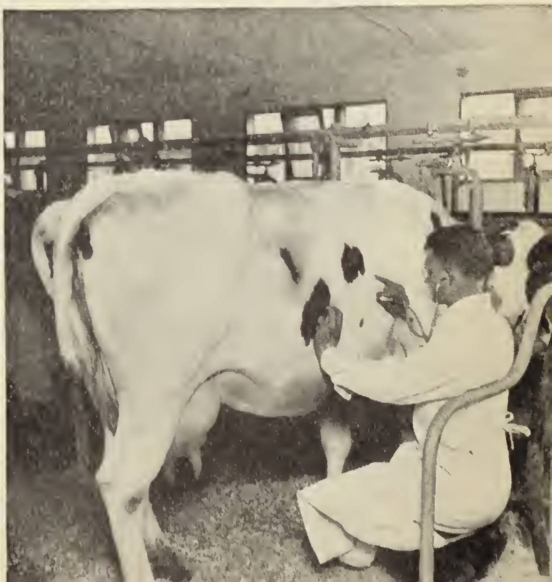
Disease may be carried by parasites which live in infected water. The liver fluke, a large worm that causes serious trouble in sheep, lives part of its life in the bodies of snails. Sheep drinking the water in which the snails live may swallow the eggs of the fluke and so become infected.

Disease parasites may also live in the soil. This is true of a disease that destroys large numbers of young turkeys —the blackleg. By keeping the young birds on a clean floor until they are big enough not to be in danger, they can be raised successfully in large numbers. Until this was discovered, the best method was to let the female turkey "hide out" her nest and brood; she generally took them far enough away to find clean ground. On the other hand, many young turkeys were lost to owls, weasels, foxes, and cats.

The fur, hair, and feathers of domesticated animals afford protection for many kinds of body parasites, of which lice and fleas are the most common. These can be controlled by cleanliness and by dusting with poisonous powders. Certain kinds of flies cause a great deal of distress and sometimes introduce disease into the blood. The famous sleeping sickness of Africa is transmitted by fly bite. Another blood-sucking animal, the tick, also frequently spreads disease. Some of these diseases may be carried to man, which is an additional reason for seeing that our domesticated animals are kept free from them.

What Pasteur Discovered. Mankind owes a great debt to the French scientist Pasteur, who studied the diseases of such domesticated animals as the silkworm, the sheep, and the chicken. These studies not only proved that disease might be caused by bacteria, but they showed how such diseases might be prevented. Pasteur was able to keep silkworms healthy by protecting them from the droppings of diseased silkworms. In other words, he recommended cleanliness and quarantine, both very important methods in disease control today.

This man is giving a cow a physical examination



Pasteur also learned to grow the bacteria of disease outside the body of the animal. By doing so he discovered that if freshly grown cholera bacteria were introduced into the bodies of chickens, the chickens would catch the disease; that if the growth of bacteria was old, or stale, it did not produce disease. He also found that chickens injected, or *inoculated*, with these stale bacteria, strangely enough, could not be given the disease later on. They became immune, as we say. A number of serious diseases in man as well as animals are prevented by this same means, or by injecting material from the blood of an animal which has recovered from the disease (*vaccination*).

So today the health of the world and the prosperity of the animal industries rest upon a foundation of cleanliness, quarantine, vaccination, and inoculation, no less than upon proper feeding and care.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The best-bred domesticated plants and animals are hardy enough to take care of themselves without help from man.
2. A weed is any plant that is not useful to man.
3. The hardiest weeds are those which have been adapted to a particular environment for many years.
4. The best way of protecting domesticated plants against weeds is to breed varieties that resist weeds.
5. Insects are a menace to man chiefly because they carry diseases that kill domesticated animals.
6. In one way or another all insects are harmful to man.

7. Though insects are the most abundant animals on earth, they have not contributed a single domesticated species for the improvement of human life.

8. When insects are in the pupa stage of development they do the greatest damage to crops.

9. The gypsy moth, a variety of silkworm, is a native insect that has done great damage to the trees of New England.

10. A parasite is any plant or animal that lives on dead materials.

11. If you want to control wheat rust in your neighborhood, you must pull up all the currant and gooseberry bushes.

12. Chestnut-tree blight has killed nearly all the horse-chestnut trees in America.

13. The bacteria that cause disease among our domesticated animals always come from the water they drink.

14. Pasteur proved that inoculation with stale bacteria is a dangerous way of trying to make animals immune to disease.

Questions for Discussion

1. Why, if weeds produce as many seeds as this chapter indicates, is not the world overrun with weeds?

2. Why is it that weeds often grow so much better than cultivated plants?

3. Have any insects been pests in your community and then later disappeared? Do you know why this happened?

4. Is it correct to say that fungi can live only on other plants and animals?

Things to Do

1. Are there any plant quarantine laws in your state? Why were they set up? How are they enforced? To what extent have they saved you money? Make a study of these laws and report on them in class.

2. Many common weeds have peculiar names, such as the locoweed, pokeweed, dogbane, and nightshade. See if you can find out where these names had their origin.

3. Make an insect collection for your school museum. Kill the insects with gasoline on cotton in a closed jar and then mount them with pins on cardboard.

4. Collect some cocoons of native moths. Keep them in a cool place outside the classroom and where they will be safe from mice. In the spring bring them in and watch the moths come out of the cocoons.

5. Make a study of some fungus growths in your community. See if you can trace the life histories of some common forms.

UNIT TWO

OUR
MINERAL
TREASURES

◆

The living world with all its blessings cannot satisfy all our needs.

Indeed, it cannot satisfy some of our very most urgent needs.

It can give us the corn and the cotton that grow in our fields, but it cannot give us the tools for planting and harvesting them.

It can give us the steers that supply us with beefsteak and leather shoes, but it cannot give us the wire to fence the steers or the knives to quarter and skin them.

Only the mineral world can do that.

◆

It is only with the help of the minerals and rocks out of which the earth is made that creatures are able to live.

It was only with the help of these crude materials that men were able to move from savagery to civilization.

We cannot understand how we use our world until we understand how we use these mineral materials.

Let us then devote the second unit of this book to a search for that understanding.

◆

CHAPTER FOUR

Why Are Mineral Materials Important to Man?

HOW MANKIND HAS GROWN UP

The Civilized and the Savage. We ordinarily think of the Stone Age as a far-off day when all men were hunters and no men were much more civilized than the beasts which they hunted. Imagine the surprise of the first Europeans who visited Australia a few hundred years ago when they found people with a very early Stone Age culture living there. Though the Australian natives hunted with boomerangs, they had never heard of such simple instruments as the ax, the arrow, or the spear. They did not know how to raise grain for food nor even how to build a house.

While other men were climbing the ladder of culture, these primitive people (and certain other peoples who more or less resemble them) had apparently stopped on one of the lower rungs. Hundreds of years after the birth of Christ they were living the life which their ancestors had lived thousands of years before. Indeed, in the primitive savages of Australia we have a picture of the life which *all* men probably once lived.

Looking at this picture and comparing it with the picture of our own lives, we are struck by the differences between them. (See photographs on the opposite page.) As students of science we are not content merely to be amazed. We want to know just what the differences between savagery and civilization are. We want to know how mankind in general has been able to rise from the one condition to the

These native Australians are primitive savages

he distant ancestors of the people who live in this house
were probably as primitive as the native Australians are today

Galloway

other. And we want to know how the civilized people of today can rise to higher and higher levels of civilization.

The best way to begin a search for this knowledge is to take an imaginary trip up the trail which leads from the Stone Age to the Machine Age. Scientists and students of history have cut away much of the mystery and uncertainty which with time have obscured the way. Let us follow the landmarks which these scholars have discovered and briefly relive in our minds the great adventure of man's journey out of the past.

The Ages of Man. Men who specialize in the study of man and his culture commonly recognize three "ages" of man: the Stone Age (Old and New), the Bronze Age, and the Iron Age. The Stone Age, when men used chiefly stone for tools and weapons, continued from the earliest period in the history of man until men rather generally learned to use bronze. The Bronze Age continued until men rather generally learned to use iron, and the Iron Age has continued until today. The Machine Age is really only the latest part of the Iron Age. Do you see why?

These "ages" do not necessarily refer to definite periods in history. They stand for different conditions of human culture. As we have seen, the primitive Australians and a few other races today are still living in a Stone Age culture. Mankind in general, however, would seem to have developed with time through the cultural stages of stone, bronze, and iron.

Exercise. Look up and make a list of the implements which the Indians were using when white men first settled in North America. What "age" of culture were the Indians living in? Do the same for the white men and state the "age" of their culture.

Men of the Old Stone Age. The man-made objects, or *artifacts*, found on the dump heaps of the earliest known human settlements were made chiefly of stone. Scientists believe that all very ancient people lived in the Stone Age stage of culture. This culture shows progress within itself. Some of its stone implements are very rough and were clearly made wholly by chipping; others are smoothly polished. In spite of progress, however, the study of artifacts shows that *during most of man's existence on earth he has lived in a Stone Age culture.*

Probably at the dawn of human history man learned to make crude stone tools. He discovered some of the uses and comforts of fire. With these accomplishments he sat down, as it were, and rested for a long, long time. He was content to live in uncomfortable caves or rock shelters. He clothed himself in skins when he troubled to clothe himself at all. He ate whatever he could find, animals or plants, dead or alive.

Such was the nature of the men who were living in Europe before the days of written history. One of the best-known races of ancient man was the bull-necked, long-armed Neanderthal man. Many skeletons of this race have been found all over Europe, and in 1939 a skeleton was discovered in faraway Siberia. These bones indicate that the Neanderthal men must have looked something like the picture on page 108. The caves that yielded the human bones have also yielded the bones of the animals which the human beings ate, the charred remains of fires, and a variety of stone tools.

Imagine yourself a member of a Neanderthal household in Europe many, many centuries ago. Glaciers stretch their icy fingers close to the entrance of your cave. The weather is always cold and damp. Your mind is dull, and your bones are crooked from lack of proper food.

Chipping stone to make tools and weapons was a major industry of Neanderthal ma

Your home is only slightly more attractive than the dark and lonely forest. The flickering fire brightens things a little, but it is never really cheerful. You learn from your parents the simple art of chipping stone. You make heavy axes for killing wild animals, sharp cleavers for skinning them, and other tools for cracking their bones so that you may eat the marrow (see above). You do not know it, but in spite of the hardness and crudeness of your life, you are helping to lay the foundation of future civilizations.

Another Stone Age race of men, the Cro-Magnons, lived longer than the Neanderthal race and reached a higher stage of culture. Many Cro-Magnon skeletons have been found in Europe, and from the appearance of these the men must have looked something like the picture on the opposite page. Though these men used stone for tools and weapons, they rather generally polished their implements and strove for artistic effect. The Cro-Magnons also used bones and horns as materials for their tools, some of which were beautifully decorated. They also drew pictures on the walls of their caves. Cro-Magnon men were clearly more able than the Neanderthalers to battle with their surroundings and at the same time to enjoy their beauty.

Men of the New Stone Age. The Neanderthalers and Cro-Magnons belong to the Old Stone Age. If we move forward now to a period much nearer to the present, we find the people of Europe living in small scattered communities and cultivating the land. Although they were still working in stone at that time, they were so much more skillful than earlier men that they are referred to as men of the New Stone Age.

Probably the greatest advance of New Stone Age over Old Stone Age peoples was their ability to fasten wooden

Cro-Magnon man was an artist as well as a hunter

handles to their stone tools and weapons. This may seem a very small achievement, but it marks great progress in the history of human culture. After the beginning of the New Stone Age, progress in cultural development seems to have been rapid. There were more kinds of implements with which to work. As a result of this, there was opportunity for a greater variety of experience and for a wider learning. Within a few thousand years after man had learned to polish stone and to fasten handles on axes, he learned to write. From that time onward we have his written record as well as the record left by his artifacts.

A new era began when man found that he could use metals for tools and weapons. Work in stone did not end, however, when work in metals began. The ruins of stone monuments (see opposite page) and the bits of beautiful statuary discovered in Egypt, Phoenicia, Babylonia, and other countries furnish a record in stone of the cultural developments of old civilizations.

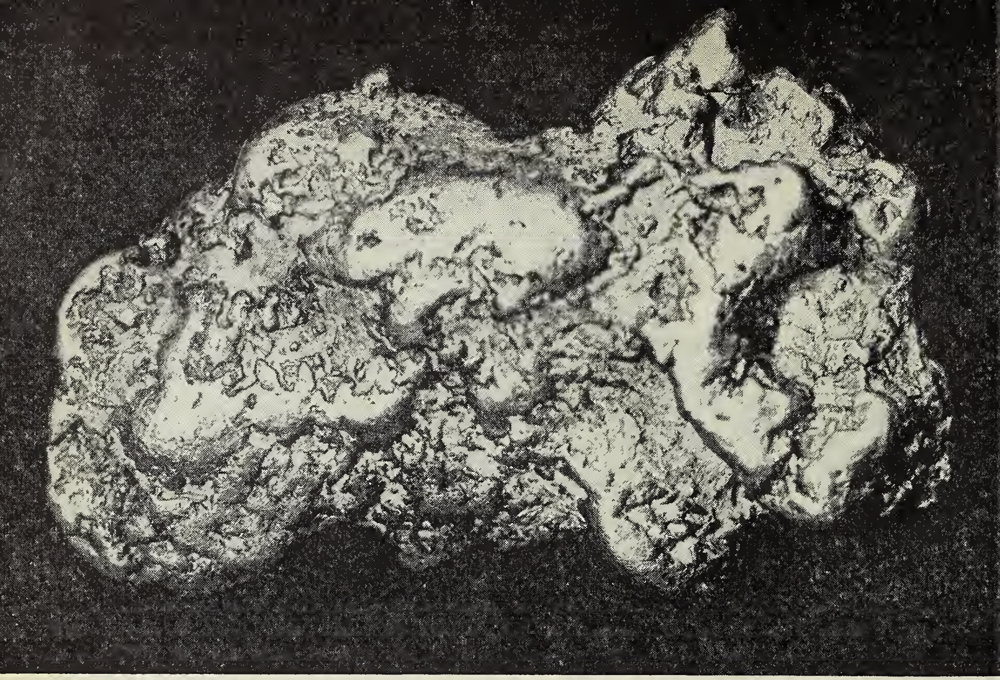
Early Use of Metals. The earliest man-made metal objects were formed from copper, silver, and gold. Though they date back many centuries, they are very modern when compared with the stone tools of Neanderthal man. No one knows which one of these three metals was used first, but all of them were in use long before the dawn of recorded history. Of the three, copper was the most abundant.

Early methods of working metals were naturally crude. Copper, silver, and gold are soft metals when pure and will not hold a cutting edge. They were probably first used for making ornaments. Artifacts of copper show, however, that this metal was used to some extent for making weapons.

Why did primitive people first discover and use these particular metals? The answer probably is that while cop-

G. E. Kidder Smith

The spirit of ancient Egypt survives in stone



Ward's Natural Science Establishment

A shiny gold nugget such as this would easily have caught the eye of primitive man

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per, silver, and gold are not generally found in very great quantities, they are found "free" in many regions. "Free" metals are those which are not joined with other chemical elements in the close unions that chemists refer to as *compounds*. They have the shiny appearance, the hardness, and the heaviness which we associate with the word "metal."

To use these "free" metals, early man did not have to know anything about the processes by which metals are extracted from the duller, softer, and lighter compounds of metals and other elements. It seems reasonable to believe that our primitive forefathers, discovering shiny nuggets of "free" metals similar to the one shown above, first fashioned them into trinkets. Later they found that for certain more practical purposes these metals were superior to stone.

Some time after man learned to work with "free" metals, he learned to extract metals from their compounds by the use of fire (*smelting*). Perhaps the discovery of smelting was made around a primitive hearth. Some sharp-eyed person may have noticed that certain rocks which did not have the shiny appearance of metal melted in the heat and gave off metallic substances. Howsoever this important discovery may have been made, it is likely that the more intelligent members of the race realized its importance and added it to their increasing store of knowledge.

The Bronze Age. Later came the knowledge of how to combine metals with one another. When certain metals are mixed with other metals, they form what are known as *alloys*. Some alloys, or mixtures of metals, are harder, tougher, or less likely to rust than any of the metals which go into their composition. These alloys are therefore much more durable than the pure metal. Copper, for example, when mixed with tin forms bronze, an alloy which is much harder than either of the metals from which it is made. When primitive people rather generally learned to manufacture bronze and to use it in manufacturing weapons, tools, and works of art, the Stone Age passed into the Bronze Age.

Exercise. How to show that bronze is harder than the metals out of which it is made: Get a piece of bronze from a dealer in junk, a piece of pure copper, and a piece of pure tin. Scratch each with a steel knife. Which one scratches the least easily? Which one is the hardest?

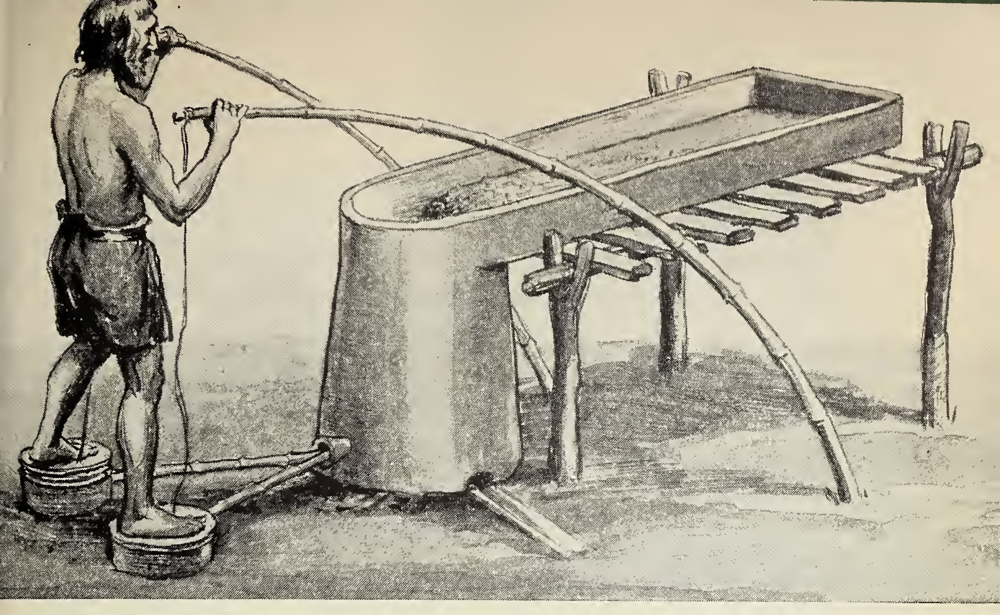
Though mankind as a whole remained in the Bronze Age only a relatively short time, more advance toward modern civilization was made during this period than during the much longer period of the Stone Age. With bronze, men could easily make a great variety of weapons and tools with strong cutting edges. Carts, chariots, armor, statues, and a great variety of other useful and ornamental bronze objects were also made during this time of cultural attainment.

The early Greeks and Romans, who showed great ability in using stone to enrich their lives, also excelled in using bronze. Some of the finest masterpieces on earth were made of bronze by these peoples during the five hundred years that came just before the birth of Christ (see below).

The Iron Age. The story of man's progress in the use of iron is similar to the story of his progress in the use of bronze. The effect of iron on human culture, however, has been greater than the effect of bronze, partly because iron lends itself to more uses and partly because compounds of iron are much more abundant than compounds of copper. Nobody knows exactly when iron began to be widely used for weapons and tools. It is clear, however, that this did

This beautiful chariot is a relic of the Bronze Age in Italy

The Metropolitan Museum of Art



is ancient furnace for separating iron from its ores was the seed from which our great modern iron industry grew

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not come to pass until a few thousand years after the discovery and widespread use of bronze.

The early iron worker separated iron from its compounds by heating a mixture of the metal-bearing rock (known as *ore*) and charcoal in a small furnace. The great difficulty was to get the furnace hot enough. Bellows made from the skins of animals were used to supply a forced draft. The drawing above shows how one of the first furnaces was used. As the workman raised his foot he enlarged the space within the skin, and air entered to fill it. As he threw his weight on the skin, the air was forced out through the furnace. This seems crude to us now, yet it represents a clever invention. Certain primitive people in Africa still make iron in much the same way. From this simple beginning the modern blast furnaces described in the next chapter have grown.

Uses for iron multiplied rapidly with time. Like stone and bronze, iron was used in making weapons, tools, and objects of art. It was also used for armor, doors, gates, and fences. In the construction of these there was early evidence of great artistic ability, as shown below. As men continued to enlarge their experiences through work with iron, they discovered more and more uses for this metal.

Perhaps the greatest achievement of the Iron Age came when James Watt improved the Newcomen steam engine and thus extended its use. He invented a piston and a cylinder similar to the ones used today. Watt took out his first patent in 1769, and the first successful engine was in operation in 1776. It was used to pump out the water which was flooding the mines in England. Had it not been invented, large-scale mining would not have been possible.

Within twenty-five years the steam engine was used widely to develop power for paper mills, textile mills, and other types of factories. In 1807 Robert Fulton used a steam engine to drive a boat up the Hudson River. An artist's idea of this event is shown on page 370. In 1829 George Stephenson used a steam engine to drive a railway loco-

This suit of plate armor proves the great skill and artistic ability of medieval craftsmen in the use of iron

The Metropolitan Museum of Art

motive. Before 1900 another kind of engine, the gasoline engine, was successfully used to drive motor cars. Soon after 1900 it was successfully used to drive airplanes.

With the rapidly developing use of such engines and machinery came a rapidly increasing demand for iron. Today we are still living in the Iron Age because iron more than any other metal shapes the character of our lives. We shall refer to the uses of this all-important material throughout this book.

Civilization and Metals. From this rapid survey of many years of human history, one very important fact stands clear. Mankind in general grew up from savagery to civilization as man learned to use the mineral materials of the earth on which he lives. The more he learned about these materials the more his range of experiences expanded. As long as men knew only the use of stone, mankind grew up very slowly. When men stumbled on the discovery and uses of metal, mankind grew up very fast. Metals are not only the key to the growth of human culture in the past, but they are also the foundation of civilization in the present. They will also very certainly be an important part of future civilization.

HOW METALS DIFFER IN CHEMICAL ACTIVITY

Composition of the Earth. The entire universe, including every star, planet, and living creature, is made up—as far as scientists can discover—of ninety-two chemical elements or their compounds. These elements and compounds are the raw materials with which men must deal, no matter what they do.

The estimated average composition of the earth's crust is given in the following table:

Chemical Element	Approximate Per Cent
Oxygen	46.59%
Silicon	27.72
Aluminum	8.13
Iron	5.01
Calcium	3.63
Sodium	2.85
Potassium	2.60
Magnesium	2.09
Titanium	0.63
Hydrogen	0.14
Phosphorus	0.13
Manganese	0.10
Carbon	0.09
Sulfur	0.05
Chromium	0.04
All others	0.20
	100.00

You will recognize some of the names in this list as those of familiar materials. Others, though belonging to materials which are abundant, may be strange to you. You may never have seen a sample of pure silicon, for example, even though next to oxygen it is the most common chemical element in the rocks. You will also notice that some very well-known materials are not listed; lead, for instance, and tin, zinc, copper, silver, and gold. These do not appear in the list because they are present in the earth's crust in such very small quantities that they are grouped under the heading of "all others." Man has been clever in discovering and using materials that are relatively rare, as well as those that are very abundant.

More than one third of the ninety-two chemical elements are metals, but only about twelve of these have any great commercial importance. Of all the metals, iron is used in greatest abundance. In one year the quantity of iron used is about thirty times that of all the other metals combined. We use so much iron because it is easy to get, because it has many different uses, and because it can easily be made hard, tough, and strong. Fortunately, many metals are widely distributed in the earth's crust. Simple and efficient processes have been invented for the extraction of them from the rocks.

Why has iron been used so much more extensively than aluminum when, as you may see in the list, aluminum is the more abundant? One reason is that good aluminum ore is not so plentiful as good iron ore. Besides, the process for separating aluminum from its ore requires more energy than the process for separating iron. The result is that even though aluminum is actually more abundant in the crust of the earth, the pure metal is much more expensive than iron.

The metals play an important part in almost everything we do

Life Magazine

The chief reason why more energy is required to extract aluminum from its ore is that aluminum has greater chemical attraction for other elements than has iron. This brings us to an important general observation. *The chemical properties of metals very generally determine their usefulness.* Let us examine these properties a little.

The Very Active Metals. Compounds of the element calcium are next in abundance to compounds of iron in the crust of the earth. Sodium and potassium follow calcium in order of abundance. Probably you have never seen any of these elements in metallic form, but you have often seen compounds of them. Marble, for example, is a compound of calcium, carbon, and oxygen which is known as calcium carbonate. Ordinary table salt is a compound of sodium and chlorine which is known as sodium chloride. Many compounds of calcium, sodium, and potassium dissolve in water. The salt in the ocean is largely a mixture of compounds of these metals.

Why is it that we seldom see calcium, sodium, and potassium as elements? The answer is partly that these metals may be separated from their compounds only by the use of much energy, which makes their production expensive. Another reason is that as pure metals they have few important uses. While this comparative uselessness is partly due to the cost, it is also due to the ease with which these elements combine with other elements. Elements that combine easily with other elements are said to be chemically "active."

Perhaps your science laboratory has samples of these highly active metals in their pure state. If so, you can very soon learn what strange substances they are. They are soft and easily cut with a knife. Your science teacher will

This boy is performing the experiment described below

warn you that you must not handle sodium or potassium with your fingers. Both these metals enter vigorously into chemical action with water and produce heat. There is apt to be enough moisture on your fingers to cause them to react and to produce bad burns. For this reason they must be handled with a pair of forceps.

Exercise. With a pair of forceps lift a piece of metallic sodium from the jar in which it is kept. Cut off a piece no larger than a grain of wheat. Hold it at arm's length with the forceps and drop it into a beaker of water. Since sodium is lighter than water, it will float on the surface. Notice that chemical action begins immediately between the sodium and the water.

When you perform this experiment, you will notice that energy is rapidly released as soon as the sodium touches the water. Enough heat is produced to melt the metal. It runs round on the surface of the water, growing smaller and smaller until it finally disappears. At the same time gas, which may be identified as hydrogen, is released by the chemical action. The sodium disappears, becoming part of a chemical compound, and this compound dissolves in the water. You may separate the compound by evaporating the water in a flat dish.

Exercise. Pour into a small flat dish about one tablespoonful of the liquid which was left after you performed the last experiment. Evaporate over a low flame. A compound, sodium hydroxide (common lye), will be left in the dish as a white solid.

The metal potassium is much like sodium. It is soft and easily cut with a knife, and it reacts with water even more vigorously than does sodium. Try it, *but remember that both these elements must be handled with extreme care.* Never pick them up with your fingers; always use a pair of forceps. Use very small pieces in your experiments. Never stand near the dish when you drop the metal into the water.

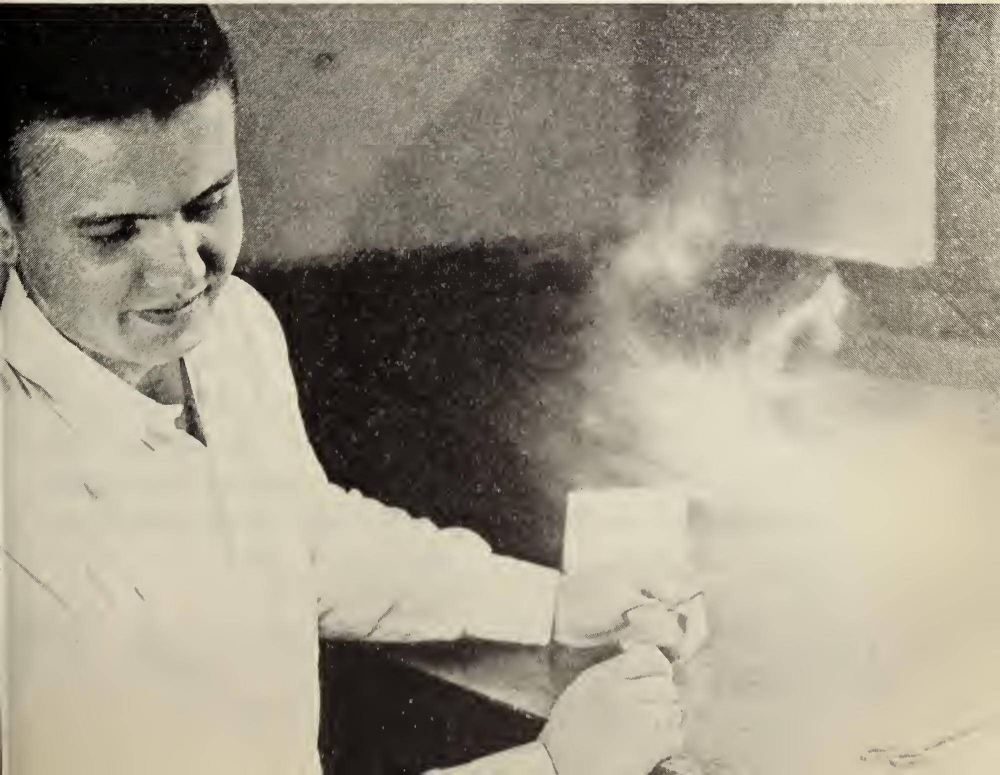
Calcium reacts with water in a similar manner, but much less vigorously.

Exercise. Place a small piece of calcium (size of a pea) in a beaker of water. Chemical action begins immediately as is shown by the escaping bubbles of gas. You need have no fear of holding calcium in your fingers. It is much harder than sodium and must be cut with a chisel or a saw. Calcium is heavier than water and therefore sinks. Hydrogen gas is slowly released in bubbles that rise to the surface as chemical action goes on between the metal and the water.

Magnesium is also one of the chemically active metals, but it is less active than calcium. While it reacts only slowly with water it reacts vigorously with oxygen. This metal is supplied to the laboratory as long strips rolled in a coil. In this form it looks like a coil of ribbon and is called "magnesium ribbon."

Magnesium will burn furiously with an intensely bright light. On account of the brightness of its flame it is sometimes used as a light for signaling. Such a flame may also be used to light the surface of the ground for forced landings of airplanes at night. Powdered magnesium is used in photographic flashlight powder.

This boy is burning a strip of magnesium ribbon



Exercise. Hold a small strip of magnesium ribbon in a pair of forceps and apply a match. The flame will be very hot and bright; so hold the forceps at arm's length and turn your eyes away as soon as the metal starts burning. The powder (magnesium oxide), a compound of magnesium and oxygen, forms when this metal is burned.

The Less-Active Metals. You may test the chemical activity of the less-active metals by the use of acid. Let us see if we can determine the relative activity of several of these.

Exercise. Place in each of five test tubes a little dilute hydrochloric acid. Arrange the tubes in a rack. In one of the tubes place a small piece of magnesium, and observe what happens. Place in the second a piece of zinc, in the third a piece of iron, in the fourth some tin, and in the fifth some copper. Which metal shows the most and which shows the least violent chemical activity?

While chemical action goes on in the above experiment bubbles of hydrogen escape from the liquid in the tubes containing the magnesium, the zinc, the iron, and the tin. These metals, as well as some others, react with acid and produce hydrogen. In the tube containing copper and hydrochloric acid there is no evidence at all of chemical action.

Do you see what a striking contrast our experiments have shown between sodium and potassium, on the one hand, and copper, on the other? Sodium and potassium react vigorously with water, and copper does not react even with hydrochloric acid. It is possible to make certain tests with silver, gold, and platinum which show that these metals have even less chemical activity than copper. Gold and platinum do not rust or become dull in the air, even when heated, because they will not react with the oxygen of the air. All the metals may be arranged in order of chemical activity between these extremes.

An arrangement of the common metals in order of their chemical activity from high to low is as follows:

Metal	Date of Discovery
potassium	1807
sodium	1807
calcium	1808
magnesium	1829
aluminum	1827
zinc	Middle Ages
chromium	1797
iron	Early historic times
nickel	Early historic times
tin	Ancient times
lead	Ancient times
copper	Ancient times
mercury	Ancient times
silver	Ancient times
platinum	Ancient times
gold	Ancient times

Note that, in general, the metals that are least active are the ones that have been known since ancient times. The metals which have high chemical activity never occur "free," or uncombined with other elements. They occur only in the form of compounds which do not look like metals and which cannot be recognized as metals until they are released from their chemical bonds. The contribution of metal workers and chemists to civilization consisted in the discovery of means of breaking these chemical bonds, so that the various metals would be free for use.

From all this you might conclude that the least chemically active metals are the most useful. It is true that for some purposes the most active metals are quite worthless.

On the other hand, some of the most important experiences of our daily life depend on the chemical activity of certain metals, as the following section will show.

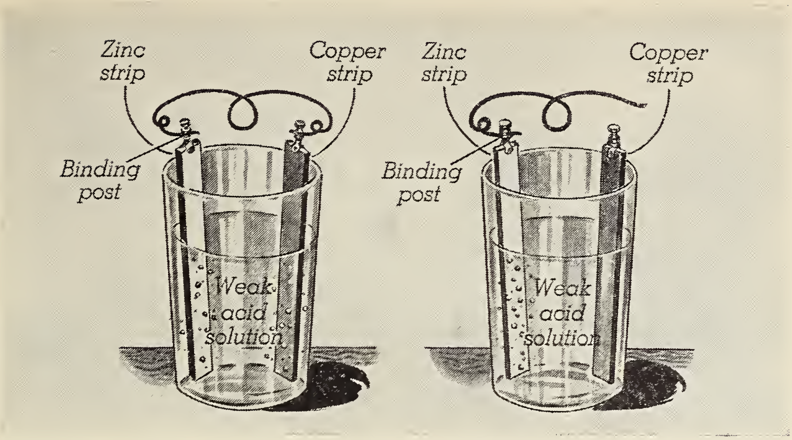
HOW CHEMICAL ACTIVITY MAKES METALS USEFUL

How Chemical Activity Produces Electricity. Modern civilization is built to a large extent on the use of electricity. Not least among the roles which metals play today is the role of producing electricity through chemical activity. A few experiments will show you how they perform this feat.

Exercise. Secure some strips of zinc and copper, preferably with binding posts attached as shown on the opposite page. Put some dilute acid into a glass tumbler. You may use either hydrochloric or sulfuric acid, but hydrochloric is better because it does not burn your clothing or your fingers so badly if you happen to spill it. Be careful, however, whichever acid you use. Place a strip of zinc in the acid. Is there evidence of chemical action? Do the same with a strip of copper. Does the copper show any activity?

Next join a strip of zinc and a strip of copper by means of a short piece of copper wire, and place them in the acid as shown in the diagram. Watch carefully and notice that there is evidence of chemical action on both the zinc and the copper. Now disconnect the wire joining the two strips. Is there still evidence of chemical action on the copper? Is there chemical action on the zinc?

It is clear that conditions in this experiment were not the same when the strips of metal were joined by the wire and when they were disconnected. Bubbles of gas rose from the surface of the copper only while it was joined to the zinc. Some of the energy which you saw released

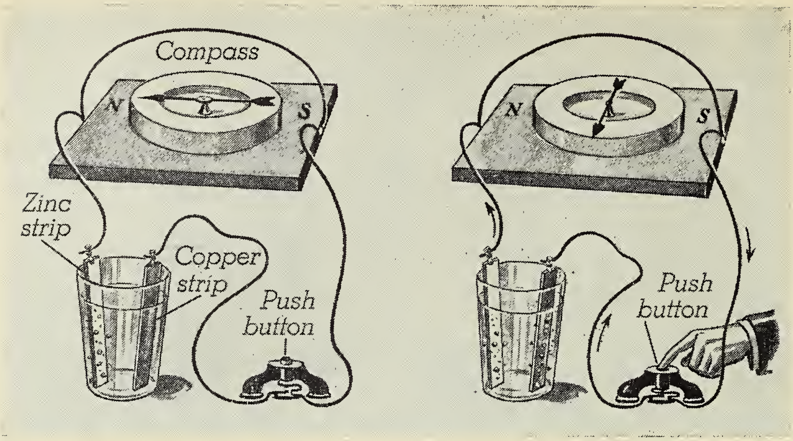


With this equipment you can produce electricity through chemical activity on metals

by chemical action between the zinc and the acid flowed along the wire from the zinc to the copper. The evidence of this flow was that chemical action showed on the copper while it was joined to the zinc, and not after it was separated from the zinc. The energy that flowed along the wire was electrical energy. It was produced by chemical action between the zinc and the acid.

You can get further evidence from another experiment that electricity will flow along a wire from zinc toward copper when strips of these metals are put into acid and connected.

Exercise. Use the equipment which you used in the last experiment, but insert a simple switch, as shown on page 128. Place a compass close to the wire as shown, and arrange it so that the wire and the magnetic needle of the compass are parallel before the strips of zinc and copper are connected. Since the compass needle will ordinarily point north and south, you must mount the



With this equipment you can study the electricity which is produced through chemical activity on metals

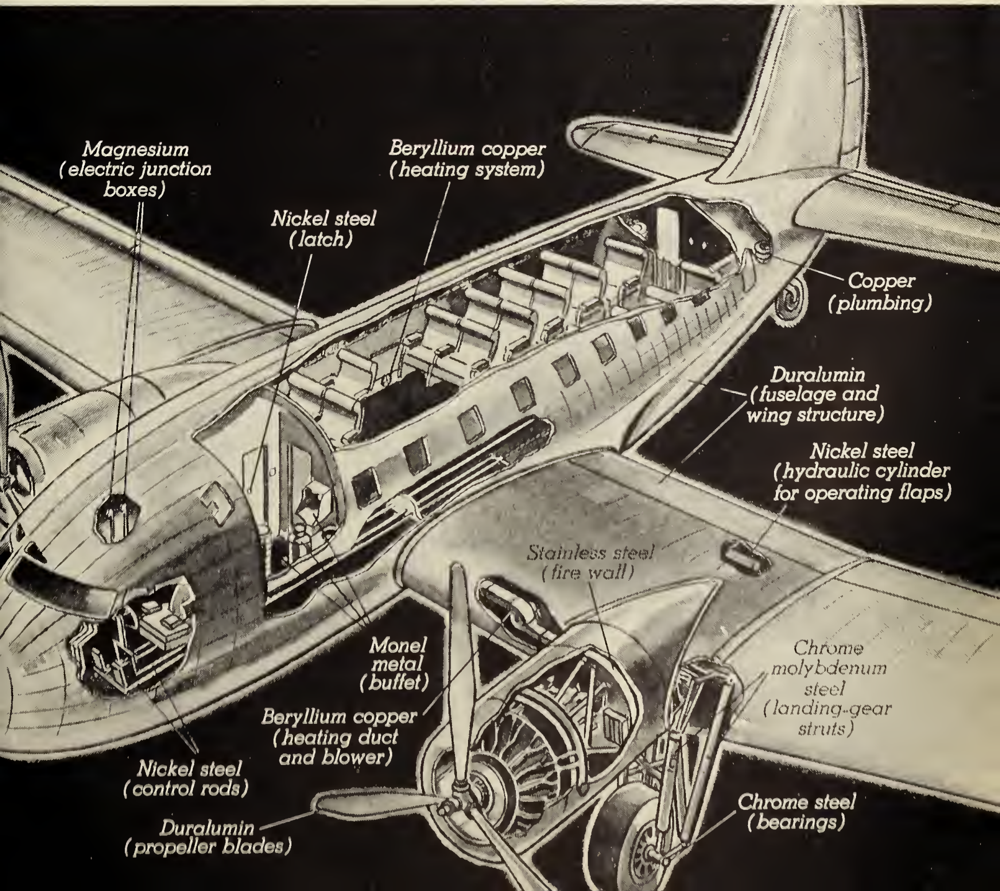
wire so that it too is in a north-and-south line. When you connect the strips by closing the switch, you will see an effect on the needle. Such an effect is produced whenever a current of electricity is flowing through a wire.

You could make further experiments to show that electricity will flow between strips of aluminum and copper, between iron and copper, between zinc and tin, and between other metals when they are placed in acid and joined by a wire. In a later unit we shall see other examples of the close relationship between metals and electricity.

Different Uses of Metals. The different metals and their compounds have different characteristics, or "properties." These properties determine how the metals shall be used. Zinc, because of its chemical activities, is used in the manufacture of dry electric cells such as those which furnish the electricity for flashlights. Other metals could be used, but no other one is so satisfactory for this particular purpose. Lead is used in storage batteries; copper is used in wires to carry electricity from one place to another; silver is made into coins. In each case the particular properties of the metal, together with its relative abundance, determine how it shall be used. You will learn more about the relation between the uses and the properties of metals as you continue your study of this unit.

How Metals Combine with One Another. Since most metals combine with elements which are not metallic, one might well ask if metals combine with one another. The answer is that they do, and the fact that they do has been very useful to man. The mixtures of metals called alloys are by no means rare. As a matter of fact, most metals are used in the form of alloys.

Many different metallic alloys are built into the modern airplane


Magnesium (electric junction boxes)
Beryllium copper (heating system)
Nickel steel (latch)
Copper (plumbing)
Duralumin (fuselage and wing structure)
Nickel steel (hydraulic cylinder for operating flaps)
Stainless steel (fire wall)
Monel metal (buffet)
Chrome molybdenum steel (landing-gear struts)
Beryllium copper (heating duct and blower)
Nickel steel (control rods)
Chrome steel (bearings)
Duralumin (propeller blades)

Steel is the most important of our metals. It is not a pure metal at all but an alloy of iron and carbon. Some steels have other metals alloyed with them. Stainless steel, for instance, contains chromium and nickel in addition to carbon. The metallic parts of airplanes are usually made of duralumin, which is an alloy of aluminum, magnesium, manganese, and copper. Fillings in teeth are generally made of silver alloyed with mercury.

There is almost no limit to the number of metallic alloys which can be made, each with its own peculiar properties. It has been estimated that there are at least 10,000 different alloys in use today. Thus man can draw upon many different kinds of alloys rather than just a few kinds of pure metals. He can usually find an alloy which is satisfactory for any task he has in mind. If civilization had to depend on the few pure metals instead of the many alloys, men would still be living primitive lives.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. There has not been a Stone Age culture on earth for many thousands of years because the Stone Age ended many thousands of years ago.
2. The Cro-Magnon men of the Bronze Age were more civilized than the Neanderthal men of the Stone Age.
3. When the Bronze Age began, work in stone ended.
4. Iron is the commonest metal in the crust of the earth and the one that was first discovered by man.
5. A "free" metal is one that is not expensive.

6. Bronze is an alloy of copper and zinc.

7. Smelting is the process of melting and mixing metals into alloys with the use of heat.

8. The Iron Age came to an end after a few thousand years.

9. Aluminum is the cheapest of all metals because it is the most abundant.

10. Calcium, sodium, and potassium in their pure forms have many important uses.

11. The chemically active metals are easier to recognize than other metals because they always have the shiny appearance, the hardness, and the heaviness which we associate with metals.

12. When strips of copper and zinc are placed in acid and connected by a wire, electricity flows from the chemically active copper to the chemically inactive zinc.

13. Only a few metals will combine with one another to produce alloys.

14. More pure metals than alloys are used in the modern world.

Questions for Discussion

1. Can one fairly say that primitive man was less intelligent than modern man?

2. Do you think that any of man's cultural progress has been due to chance discoveries? Should you say that more of it has been due to chance than to careful studies and experiments?

3. Why should it be easier to separate gold and platinum from compounds than to separate potassium and sodium?

Things to Do

1. Trace the history of the development of the automobile or some other machine, either by dates or by a series of pictures.

2. Test various metals for their capacity to produce electricity. Take strips of different metals of the same size, a tumbler of acid, and a compass. How can you determine which of the metals has the greatest capacity for the production of electricity?

3. Substitute a rod of carbon for the strip of copper in the experiments described on pages 127–128. Use a compass to determine which metal joined to carbon with a wire gives the strongest, and which the weakest, flow of electricity.

4. Titanium, vanadium, tungsten, thorium, and uranium are among the rarer metals. Look them up in an encyclopedia and make a list of their uses.

CHAPTER FIVE

How Do We Make the Metals Serve Us?

IRON IN THE MODERN WORLD

Iron in the Drama of Our Lives. Our lives are a drama, and the world is the stage on which the drama is enacted. Though the scenery of the play is forever changing, the material out of which the scenery is made remains pretty much the same. For the scenery is made to a large extent of iron.

Think of the many things that are composed wholly or largely of iron. Railroads, automobiles, trucks, tractors, skyscrapers, bridges, ships, heavy machinery for the manufacturing industries, thousands of small articles such as screws, hammers, and wrenches,—all are made largely from iron and its alloy, steel.

To get an idea of the importance of iron in our daily lives, let us consider our "daily bread." Machines of iron, as shown on page 135, are connected with every step in the process that changes the grain that starts in the field to the bread that ends on the table. The plow that turned the soil was made of iron, and so was the tractor that pulled the plow. Iron went into the machine that cut and threshed the grain. The truck and the train that hauled the grain to the flour mill, and much of the mill itself, were made of iron. So were the carriers that delivered the flour to the bakery and the machinery that mixed the dough, baked the bread, and finally brought it to us.

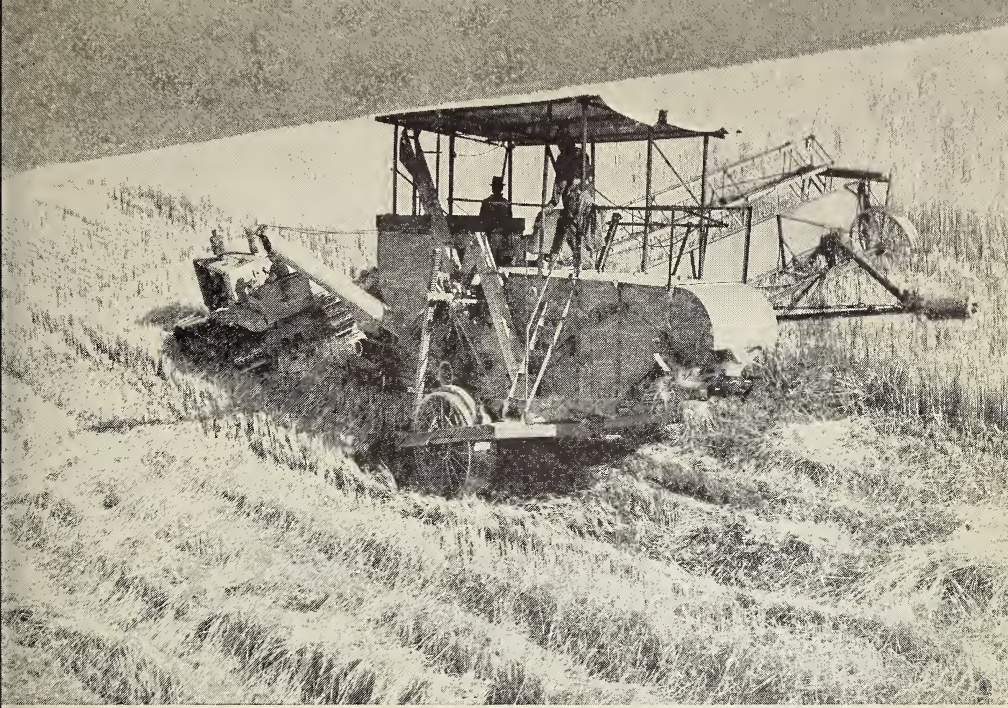
There are many other similar examples of the importance of iron in modern life. Our clothing, houses, furniture, parks, and roadways, to mention only a few, are produced and maintained by machines of iron.

Exercise. Look round your science classroom and make a list of all the articles that contain iron or one of its alloys. Make a second list of the articles that contain no iron but which you believe required iron for their manufacture. Make a third list of the articles that neither contain iron nor required iron for their manufacture. Which list is the longest? Which is the shortest?

Where Iron Occurs. Where do we get the iron that we see wherever we go? Obviously we must get it in the first place from the crust of the earth. The table on page 118 shows that iron makes up 5 per cent of the earth's surface. The reds, browns, yellows, greens, and purples in the landscape are produced very largely by compounds of iron. If you were a skillful chemist, you could extract iron from the soil of your own back yard; but it would be a slow, difficult, and expensive task.

When men go into the business of mining iron, they do not dig just anywhere. They pass by the common rocks and dirt which contain a little iron, and mine only the rocks that contain a great deal of iron. There are certain areas scattered over the surface of the earth where the rocks contain more than 50 per cent of this metal. *These rocks which are rich in iron and from which the metal can be extracted easily and profitably are known as iron ores.*

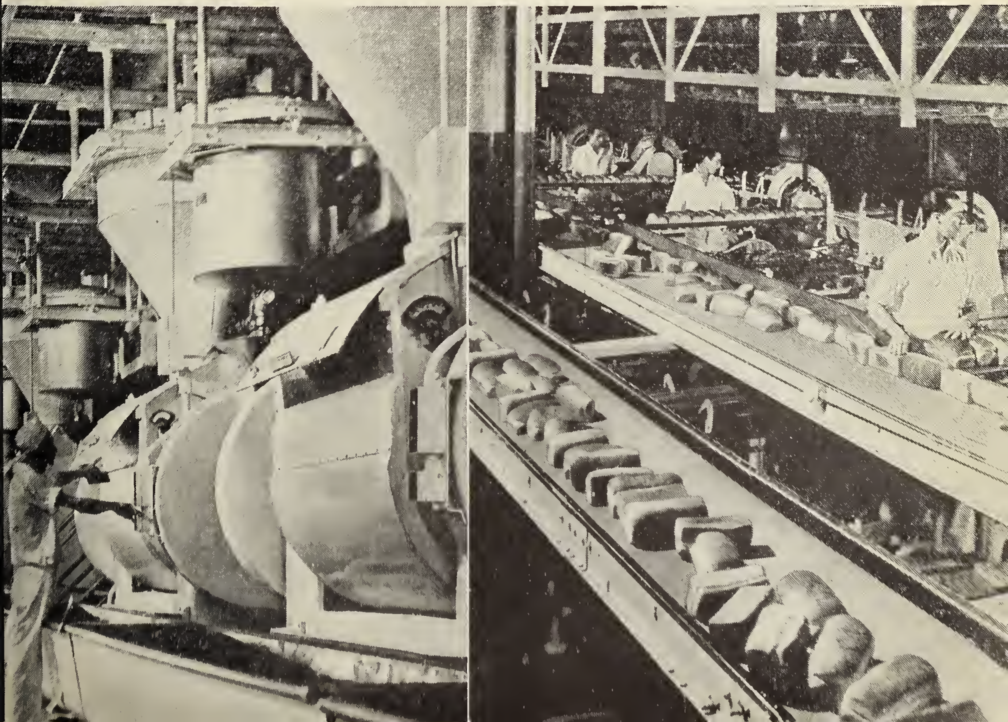
The map on page 136 shows the locations of rich iron ores in the United States. Other famous deposits occur in northern France, southern Germany, Brazil, South Africa, Newfoundland, and Cuba. There is no immediate danger of

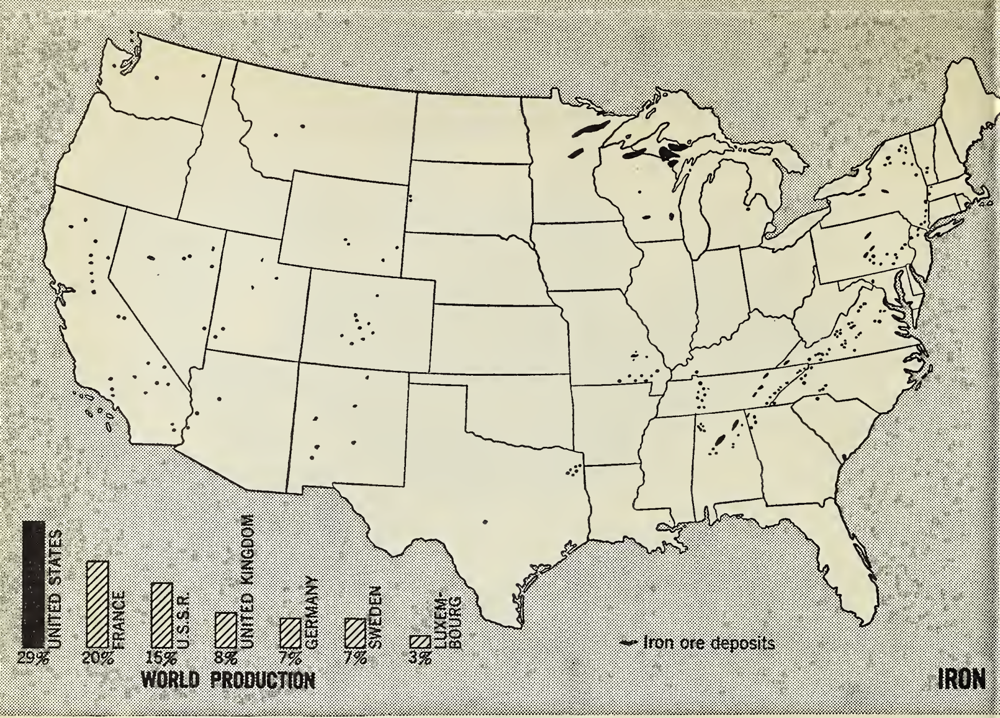


Iron machinery harvests wheat for our daily bread

on mixers (left) stir up great batches of dough. Traveling belts (right)
carry bread from iron cooling racks to iron slicing and wrapping machines

Bond Bread Bakers





This map tells the story of iron production in the United States

shortage of this important metal, though our distant grandchildren may have to pay higher prices for iron than we pay today.

Exercise. If you do not already have a collection of rocks, minerals, and ores in your school museum, you might wish to prepare such an exhibit now. Begin with specimens from your immediate vicinity. Try to include ores of each of the common metals. If you have friends in other cities, ask them to trade specimens which are common in their neighborhood for specimens which are common in yours. By building up a good collection of local specimens, and then by trading, it is possible to gather together a fine collection at very little cost.

The Ores of Iron. The most common ores of iron are those that are rich in the minerals hematite or magnetite. If you do not have samples of these ores in your school museum, get them from a chemical-supply company. Remember that iron ores are mixtures of iron-bearing minerals with other minerals. In asking for samples, ask for the iron ores and not merely for the iron minerals.

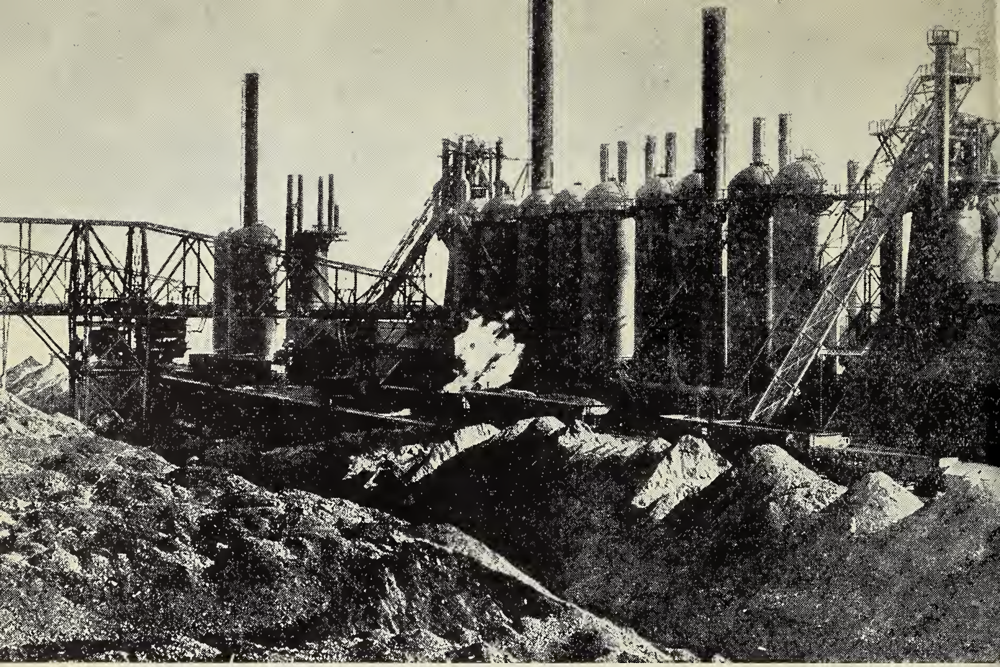
Hematite ore is generally reddish brown. There is little in its appearance to suggest that it is the material from which such things as steel rails and watch springs may be made. Some of the very best hematite ores look like mere red dirt. *Magnetite* ores are darker. They are so named because some of them have the power of a magnet. Certain kinds can attract bits of pure iron, and when a specimen is floated on a block of wood in water it will line up in a north-south direction like the needle of a compass.

Exercise. Compare the properties of hematite and magnetite ore. Test each one for magnetic properties.

---

is tremendous gash in the earth is a Minnesota iron mine. Hematite ore is scooped by steam or electric shovels, loaded on cars, and sent to Duluth. From there it is ried by boat to blast furnaces in cities along the southern shores of Lake Michigan and Lake Erie

Sawders



Inland Steel Company

In this modern blast furnace iron is extracted from iron ore

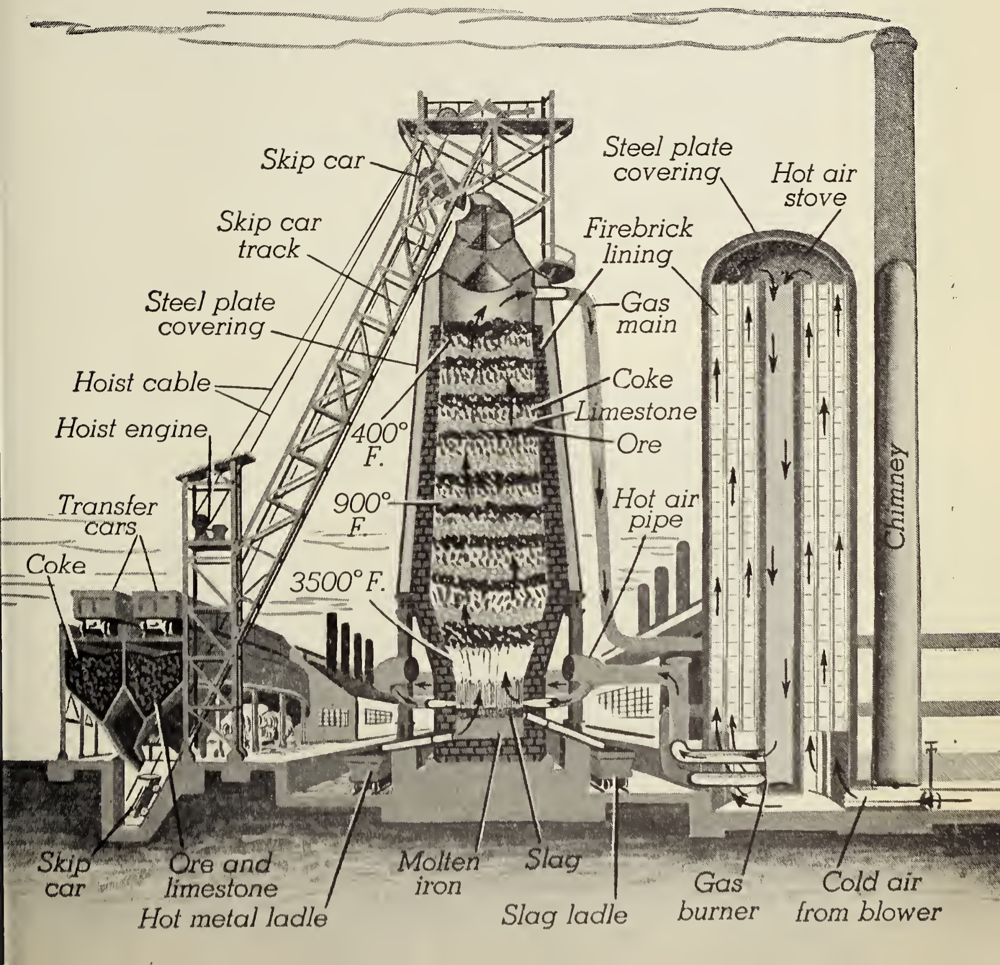
How Iron Is Separated from Iron Ore. Metallic iron is separated from such ores as these by a chemical process. This process is designed to accomplish two results. The *first* is to separate the iron minerals in the ore (generally hematite or magnetite) from the other minerals (which are made up of silica, aluminum, sulfur, lime, and a variety of other materials). The *second* is to separate the iron of the iron minerals from the oxygen with which it is generally combined.

These two ends are achieved by the *blast furnace,* one of the most valuable inventions of modern times. If you live near or have driven through a city where iron is made from iron ore, you will be familiar with the scene shown above. The great stacks (in some cases 100 feet tall and 17 feet wide at the bottom) are blast furnaces. They are made of rounded steel plates on the outside and fire bricks (which will not melt under intense heat) on the inside.

Below is a diagram that shows how such furnaces work. Notice that coke, limestone, and iron ore are fed in at the top of the furnace and that heated air is blown in at the bottom. The temperature at the bottom of the furnace rises to 3500° F. You can get some idea of the intensity of this heat when you remember that water boils at 212°. It is necessary to have such great heat because iron does not melt until it reaches a temperature of 2754°.

The hot air not only helps to burn the coke and to break

is diagram shows how coke, limestone, and iron ore are hoisted into a blast furnace l converted into molten iron and slag. Notice the oven at the right where air is heated and fed as a "blast" into the bottom of the furnace



down the ore and the limestone, but it reacts with the coke to form the poisonous gas carbon monoxide. This gas, coming in contact with the compounds of iron and oxygen in the ore, unites with the oxygen to form the harmless gas carbon dioxide. The iron is thus freed from the oxygen, and it trickles down as a white-hot liquid to the bottom of the furnace. The carbon dioxide passes out at the top.

While this is happening the limestone combines with clay and other impurities in the ore to form a glassy substance called *slag*, which floats on top of the iron at the bottom of the furnace. From time to time the iron is drawn from the furnace ("*tapped off*") through one clay-lined trough and the slag through another. Because the iron was once carried into molds that looked something like little pigs, it was known as *pig iron*. Though such molds are not generally used any more, the iron from blast furnaces still goes by the name of pig iron.

To be efficient, a blast furnace must work day and night, as well as Sundays and holidays. Once the monster cools off and cakes up, it requires a week of hard work to get it into operation again. Wise managers, accordingly, try to avoid shutdowns. They try to keep their charges forever at work.

How Iron Is Made into Steel. Like pig iron, steel is an alloy of carbon and iron. The difference between the two alloys is chiefly a difference in the percentage of carbon. Pig iron contains from 3 to 5 per cent carbon, while steel contains only 0.1 to 1.0 per cent. Hence, *the process of making steel consists in removing some of the carbon from the pig iron.*

Exercise. Look up the open-hearth and Bessemer processes for making steel and report on them in class. If there is

U. S. Steel Corporation

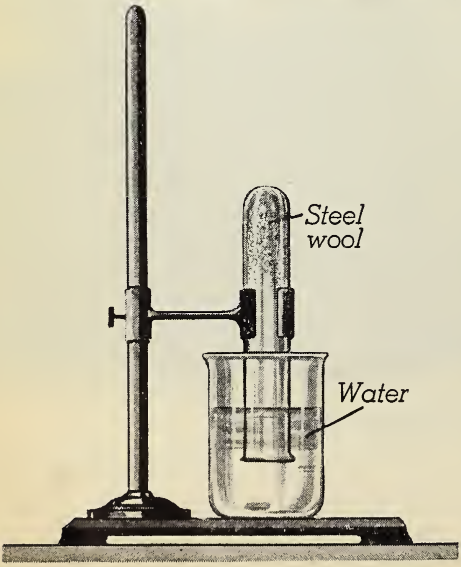
These men are "tapping off" molten iron from a blast furnace an iron foundry or a steel mill in your neighborhood, see if you can arrange to have your class shown through it. There are few more interesting places in the modern world.

What Happens When Iron or Steel Rusts. The chemical change that takes place when iron or steel rusts is in a sense the opposite of the change that takes place when iron is made from iron ore. In the blast furnace the iron is *separated* from the oxygen. When iron rusts, on the other hand, it *combines* with oxygen, forming a compound similar to the mineral from which it was made.

Exercise. How to demonstrate what happens when steel rusts. Place some steel wool in a test tube and mount it over a beaker of water, as shown below. Let it stand overnight. Does the steel wool take on a coating of rust? Does the rust look like any ore of iron that you have studied in this chapter?

How may iron structures be protected from rust? The answer is, by preventing oxygen from getting to them. Painting is the most obvious method of doing this because paint acts as a barrier between the iron and the oxygen of air and water. No doubt you have seen the "stainless" steel alloys which are widely used for cutlery. These are not strictly rustproof, although under ordinary conditions of use they are nearly so. They make up part of the answer to the problem of rust.

With this equipment you can demonstrate what happens when steel rusts



Without some artificial protection all iron objects will go down in time before their greatest enemy, rust. Is the illustration below familiar? It is estimated that throughout the world some twenty-nine million tons of iron rust away every year—a frightful waste of wealth.

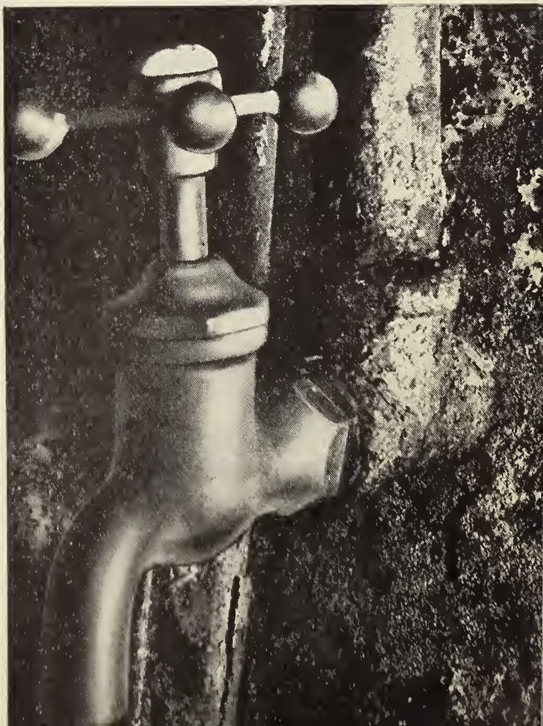
The Different Kinds of Iron and Steel. Science has made it possible for the steel industry to turn out some five hundred different kinds of iron and steel. We have seen that all steel contains some carbon, an element which in the proper amounts helps to make steel both hard and strong. Steel with a considerable amount of carbon is called "high-carbon" steel and is widely used for making springs. Somewhat less carbon is put into the steel that goes into locomotives, and still less into that which goes into bridges.

Exercise. How to show that steel contains carbon. In one test tube place a few small pieces of pure iron, and in another a few small pieces of steel. Cover the metal in each tube with dilute nitric acid. The metal dissolves in the acid and little black particles of carbon remain in the test tube that contained the steel.

The element manganese is frequently used to make steel tough as well as to reduce its expansion and con-

This iron pipe is losing its battle with rust. The faucet is unrusted because it is made of brass

Keystone



traction when heated and cooled. Nickel also helps to make steel strong. Chromium helps to prevent rusting, and stainless steel may contain as much as 12 per cent of this metal. Vanadium and tungsten make steel very hard. They are added to many tools, including those which are used for cutting softer kinds of steel.

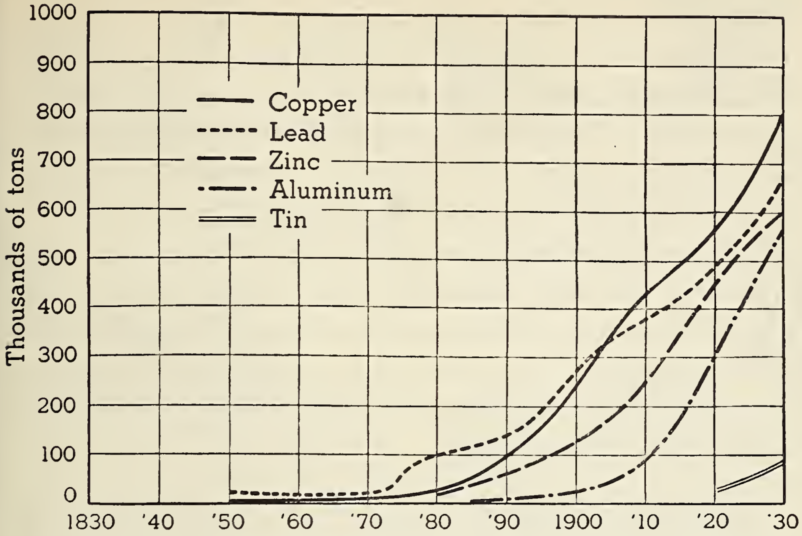
Thus other metals are brought in to help the king metal do its work. These other metals also do work of their own. The need for metals in modern civilization is so great and varied that iron alone cannot satisfy it. Copper, lead, zinc, aluminum, silver, gold, and a host of lesser metals and alloys make up part of the scenery for the drama of our times, as we shall see in the following pages.

MODERN USES OF COPPER, LEAD, AND ZINC

The Importance of Metals Other than Iron. The quantity of iron used today is many times greater than that of all other metals put together. The industries of today, however, could not exist on iron alone. A number of other metals are needed, the importance of which is shown in the table below. The figures stand for the number of short tons of each metal which were produced in the United States during one year (1939).

Pig iron	35,700,000	Aluminum	163,545
Copper	749,000	Silver	2,226
Lead	430,200	Mercury	684
Zinc	506,300	Gold	191

The demand for such metals as copper and lead has increased with the years, just as has the demand for iron. Copper, for example, was used very little before the great modern expansion of the electrical industries. Only about



The use of metals in the United States has steadily and rapidly increased

seven hundred tons of copper were produced in the United States in 1850. Nearly fourteen hundred times as much as that is produced today, chiefly because copper is an excellent material for electric wires. The demand for lead likewise increased enormously after men learned to make storage batteries. The same increasing demand is true of practically all other metals.

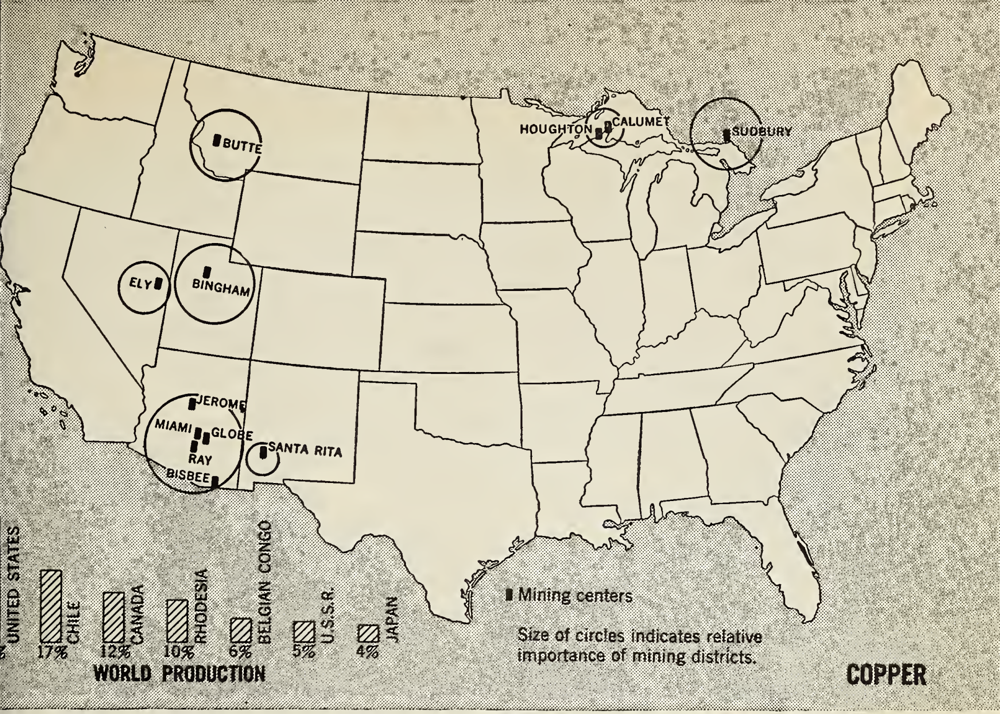
Copper and Electricity. You probably know copper best in the form of wire. Hundreds of thousands of miles of copper wire are strung over the surface of the earth. This wire makes possible a world-wide communication by telephone and telegraph. It also makes possible the distribution of electrical energy for light, heat, and power to almost every nook and cranny of the civilized world.

There are several reasons why copper is used for electrical purposes. It is one of the best carriers (*conductors*) of electricity. It may easily be drawn into wire. It does not rust, and it is fairly abundant and cheap. Why, you might ask, wouldn't such metals as iron, silver, or aluminum do just as well? The answer is that iron rusts and, besides, is not nearly so good a conductor of electricity as copper. Silver is a better conductor than copper but is much too expensive for ordinary use as wire. Aluminum is also a good conductor and, like copper and silver, it does not rust. The cost of aluminum has come down enormously during recent years and this metal is now being substituted for copper in some electric transmission lines. But copper is easily still king in the world of wire.

Mining and Smelting of Copper Ore. You will recall from Chapter Four that copper is not active in chemical change. Since it does not combine readily with other elements, it is often found in mines as "free," or "native," copper. The great native copper mines of northern Michigan were

Copper wire binds together all regions of the civilized world

Western Electric Company



This map tells the story of copper production in the United States

worked by the Indians before Columbus discovered America. The most abundant copper ores, however, contain compounds of copper with oxygen or sulfur (known to chemists as *oxides* and *sulfides*). About seven eighths of America's present copper production comes chiefly from the copper oxides and sulfides of Arizona, Utah, Montana, and Nevada, as shown in the map above. It is easy to separate the metal from such compounds.

Exercise. How to separate copper from copper oxide. Mix about equal parts of black copper oxide in the form of powder with finely powdered charcoal (carbon). Place the mixture in a test tube and heat over a flame. Let it get very hot, and continue heating for two or three minutes. After it has cooled, pour the mixture from the test tube onto a piece of white paper. Is there evidence that metallic copper has been separated from the oxide?

C. J. Strakal

The largest smokestack in the world carries poisonous waste products high into the air above the copper smelter at Anaconda, Monta

The photograph on this page shows the great copper smelter at Anaconda, Montana, where copper oxides and sulfides from the rich mines of near-by Butte are refined on a gigantic scale.

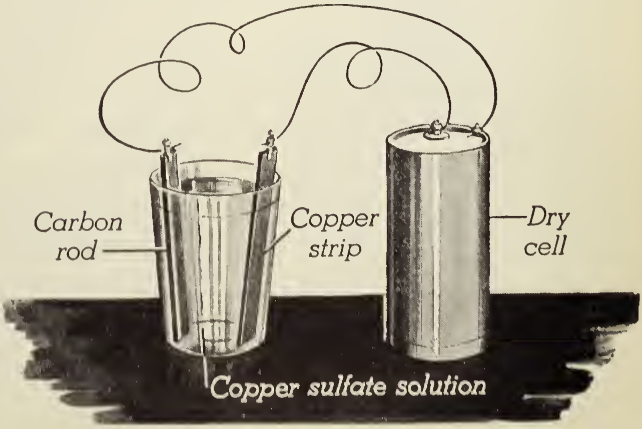
Electrolysis. Copper used in the electrical industries must be pure. Copper wire containing as little as 0.8 per cent arsenic or 0.5 per cent silica offers more than three times as much resistance to the flow of electricity as wire that is free from these impurities. Nearly pure copper is prepared by a process which is known as *electrolysis*. You may easily demonstrate this process in the laboratory.

Exercise. How to obtain pure copper by electrolysis. Set up apparatus like that shown below. Place in the tumbler a solution of copper sulfate and add a few drops of sulfuric acid to it. Set a strip of copper and a rod of carbon (in the form of graphite) in the solution and attach them with wires to the terminals of a dry cell. The central terminal of the dry cell must be attached to the copper and the side terminal to the carbon. Leave the dry cell connected in this manner for a few minutes and then take the carbon from the solution. A coating of nearly pure copper will have formed on the carbon rod.

This process of electrolysis is the same as the process used in *electroplating*. The carbon rod of our experiment is said to be electroplated, because a thin layer or plate of pure copper has formed upon it through the action of the electric current. You may electroplate a knife blade in the same way merely by putting the blade in the solution in place of the carbon rod. Silver-plating and gold-plating are done in the same way as copper-plating. In silver-plating a strip of silver must be used in place of the copper, and a solution of a silver compound in place of the copper sulfate. For gold-plating a strip of gold and a solution of a gold compound must be used.

Exercise. Make a list of all the uses which you have seen of metal "plating." How many different metals have you seen used for this purpose?

With this equipment you can obtain pure copper by electrolysis



All the copper in electric wires has been purified, or refined, by a process which is similar to electroplating. In refining copper a large plate of the unpurified copper is used. Instead of carbon, a thin plate of previously purified copper is used. When placed in copper sulfate and electrically connected as described above, copper continuously goes into solution from the plate of impure copper. At the same time a growing deposit of pure copper is formed on the thin plate of pure copper. In this way the impure copper is turned into pure copper.

Uses for Copper Alloys. In addition to its use in the manufacture of brass (copper and zinc) and bronze (copper and tin), copper is used in other alloys. Do you know that *all* metals used in the manufacture of coins are alloys of copper? One-cent pieces, as we have seen, are made of bronze. Our five-cent piece (nickel) is three-fourths copper and one-fourth nickel. Silver coins are 90-per-cent silver and 10-per-cent copper. Gold coins are 90-per-cent gold and 10-per-cent copper. Each alloy has properties that make it useful for particular purposes. The mixture of copper with gold and silver, for instance, makes these metals harder. So mixed, they do not wear away so rapidly with the constant rubbing that coins must undergo.

Exercise. List all the uses of copper and copper alloys with which you are familiar. See which member of the class can make the longest list.

Under normal conditions we use copper in the United States at the rate of about 750,000 tons per year. Of this amount about one half is copper that has been used before. The other half comes directly from the mines. Thus our reserves of copper (like those of all other metals) are being rapidly reduced. So important is the matter of the exhaustion of metals that we have reserved an entire chapter for this problem in a later unit on conservation.

Importance of Lead and Zinc. Next to iron and copper, lead and zinc are the metals that have the greatest variety of uses in the world today. The ores of these metals are not common; but they do occur abundantly in certain places, and they usually occur together. Though lead and zinc are neighbors in the crust of the earth, no two metals could differ more widely either in chemical properties or in the uses made of them. Let us see what these properties and uses are.

Lead in Storage Batteries. Lead is extensively used for making pipes, paint, and many other necessities of modern life, but its most important use is in the manufacture of

These bars of lead are about to be made into paint

Rittase from Sherwin-Williams Company

storage batteries. Every automobile has a storage battery to develop the electricity needed to fire the fuel, and all storage batteries used in automobiles contain lead plates. A cross section of such a battery is shown on page 153.

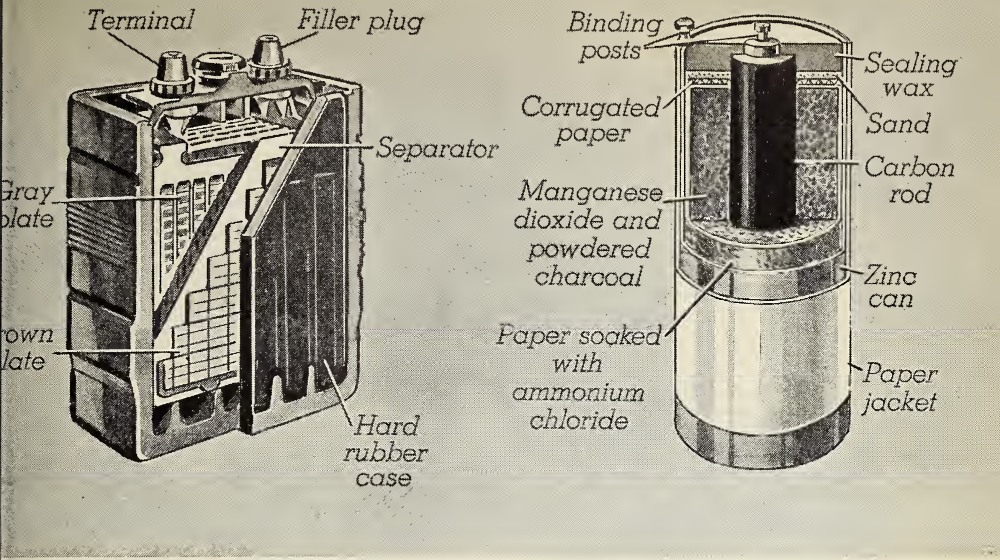
If you could examine the plates of one of the cells in a storage battery, you would see that they are not alike. One plate is gray in appearance; the other is dark brown. The gray one is made of lead; the brown one is covered with a compound of lead known as lead peroxide. The plates are set in a solution of sulfuric acid. When the binding posts on the plates are joined by a wire, electricity is developed which flows through the wire.

Exercise. Go to a garage where storage batteries are sold or recharged and ask if you may examine a battery that has been taken out of its case. Study the arrangement of the plates in the cells and the electrical connections. Write a report for your class on "The Inside of a Storage Battery and How It Works."

Zinc in Dry Batteries. Just as lead forms an important part of storage, or wet, batteries, zinc forms an important part of dry batteries (or dry cells, as they are generally called).

Exercise. How to find out how a dry cell is made. Take the paper cover off an old flashlight battery. Directly beneath it you will find a can which is made of zinc. Cut this can down through the middle with a saw or a strong pair of tin snips. The illustration on the opposite page will help you to interpret what you see.

Inside the zinc can is a layer of absorbent paper which has been thoroughly moistened with a solution of ammonium chloride. Inside the paper is a black mixture composed chiefly of powdered charcoal and manganese dioxide.



ese drawings explain the construction of a storage battery (left) and a dry cell (right)

These substances also have been well moistened. The cell is therefore not really dry; if it were, it would not work.

Through the center is a carbon rod extending nearly to the bottom of the zinc can. This rod does not quite touch the absorbent paper at the bottom of the cell. The can is sealed across the top with sealing wax, pitch, or some similar substance. This holds the carbon rod in place and prevents evaporation of moisture. The sealing material is a poor conductor of electricity; so electricity does not flow through it between the zinc can and the carbon rod.

You have observed in an earlier experiment that zinc acts chemically with acid. There is similar chemical action between zinc and ammonium chloride. When the binding posts attached to the zinc can and the carbon rod are joined with a wire, electricity is developed which flows along the wire.

The fact that zinc is a chemically active metal makes it useful for dry cells. Earlier in this unit you observed that

National Enameling and Stamping Company

This iron washtub is being coated with zinc (galvanized) to prevent rusting

magnesium is more active than zinc. Because of this, would not magnesium make even better dry cells than zinc? The answer is Yes, but more expensive ones. If the world supply of zinc ores were reduced until zinc was much more expensive than it is at present, magnesium would undoubtedly be substituted for it in the manufacture of dry cells.

Galvanized Iron. Another use of zinc is for "galvanizing" iron. Galvanized iron is iron covered with a thin coating of zinc. More zinc is used for this purpose than for any other. Many buckets and garbage pails are made of galvanized iron. Sheet iron is usually galvanized because zinc protects the iron from rusting.

When zinc is exposed to air a chemical change takes place which is similar to the change that goes on when iron rusts. A thin layer of a zinc compound forms over the surface of the zinc. This compound of zinc, however, is different from iron rust in one very important respect: it sticks fast to the surface over which it forms and protects the metal from further change. Iron rust, on the other hand, scales off as it forms and leaves fresh surfaces of metal exposed to the air.

ALUMINUM, THE "NEW" METAL

Discovery of Aluminum. Though aluminum is one of the commonest elements in the crust of the earth, it is a newcomer among the metals used in industry. It was first separated from one of its compounds about 1825, but only an extremely small amount was produced. As late as 1885 the metal was almost unknown outside chemical laboratories. During that year not more than three tons was produced in the whole world. In the same year the world production of gold was more than 200 tons. About 1886, however, a method was perfected by which metallic aluminum could be produced in large quantities. From then on there has been a rapid increase in the rate of its production, as shown in the chart on page 145.

Aluminum is the most abundant of all metals. It makes up more than 20 per cent of common clay. Ordinary clay, however, is not an ore of the metal because no practical method has yet been discovered for extracting the aluminum from it. The ore from which aluminum is obtained is a compound of aluminum and oxygen called *bauxite*. It is not so abundant as iron ore, but it is found in considerable quantities in several regions.

You have learned something about the methods used by primitive men to separate copper and iron from their ores. Why didn't some early experimenter hit upon a method for doing the same thing for aluminum? Part of the answer is that until recently there was no known source of energy which could have made this possible. Metallic aluminum is a product of the modern process of electrolysis, which we studied on pages 148–150. Before the days of electricity aluminum was locked up tightly in its compounds.

The Low Density of Aluminum. The most striking property of aluminum is its lightness, or low density. *Density is merely the weight of a given volume of any material.* Let us see what this means by actually comparing the density of a block of aluminum with the density of blocks of iron, lead, and copper. In order to make these comparisons you will need a metric balance, a graduated cylinder, and blocks of the different metals, as shown on page 157.

Exercises. How to determine the density of different metals. Begin with the block of aluminum. Find its weight in grams as carefully as you can and record it. Next pour some water into a graduated cylinder and record the quantity in cubic centimeters as accurately as you can. Put the aluminum in the water and again read the level of the water. How much higher is it? Subtract the first reading on the cylinder from the second, and the answer will be the volume of the aluminum in cubic centimeters. Do you see why? Divide the weight of the aluminum in grams by its volume in cubic centimeters and thus find the weight of one cubic centimeter of the metal. This is the density of aluminum.

In a similar manner find the density of iron, copper, and lead. Which is most dense? Record your findings in a table with a column for the metals tested and columns for weight, volume, and density.

A block of aluminum weighing 340 grams was found by one class to have a volume of 125 cubic centimeters. That means that the density of the aluminum was about 2.7 ($340 \div 125 = 2.72$). A block of steel of 125 cubic centimeters was found to weigh about 960 grams. The density of steel is therefore about 7.7, nearly three times the density of aluminum. The low density of aluminum suggests the uses which may be made of it. Because of its lightness nearly all airplanes are now made of aluminum alloyed with certain other metals to increase its strength.

Aluminum in Trains and Airplanes. There are many uses in railroads as well as in automobiles, airplanes, and dirigibles for strong, low-density alloys. The average passenger train with ten steel cars weighs more than 1000 tons. The engine alone weighs over 300 tons, and each car weighs about 80 tons. What an enormous saving in fuel there might be if railroad trains could be made of aluminum alloys! Some new trains, indeed, have already been built

This boy is determining the density of different metals

of such alloys. You can get some idea of the value of aluminum in saving fuel from the fact that one of these aluminum trains has a total weight, engine and all, of 80 tons —the weight of one car in an ordinary steel train.

We are using aluminum in the United States today at the rate of about 100,000 tons per year. This is a small amount compared with the amount of iron that is used. With the rapid increase in airplanes, which depend on aluminum for wings, fuselage, engines, and propellers, there will certainly come a rapid increase in the use of this metal.

Exercise. Go through your house and list all the articles which you believe are made of aluminum or aluminum alloys. Pay special attention to the kitchen.

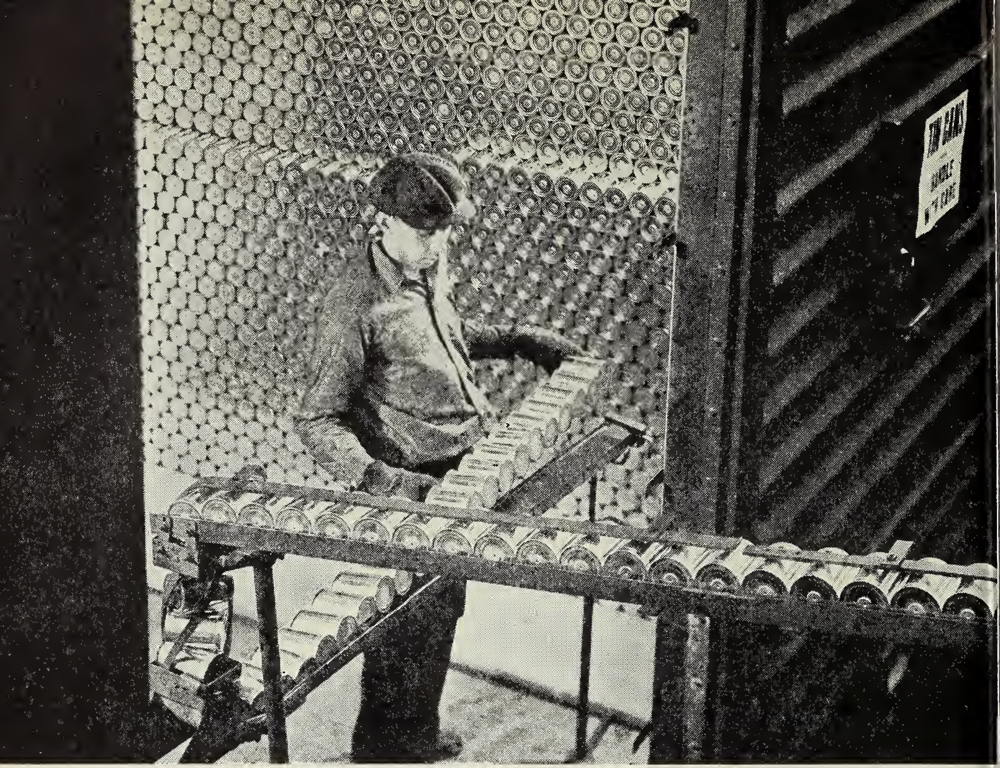
The Age of Aluminum. The cost of aluminum today is considerably greater than the cost of steel, but as its use is extended its cost will certainly go down. Before long somebody may discover an efficient method for making aluminum from clay. Because of the abundance of possible ores, it may be expected that this metal will, in large measure, take the place of iron and steel. In fact, there are very good reasons to think that we may gradually shift from an Age of Iron to an Age of Aluminum, just as earlier in human history there were shifts from an Age of Stone to an Age of Bronze, and from an Age of Bronze to an Age of Iron.

THE MINOR METALS

Use of Tin. Among the less abundant metals which are useful in the modern world, tin is undoubtedly the most common. You see tin almost every day in the form of the tin in tin cans, the tinware used in the kitchen, and in

Life Magazine

Aluminum is the mother of the modern airplane propeller



American Can Company

Most people know tin only in the form of tin cans, which are really iron cans thinly coated with tin

tin foil. None of these things really contain much tin. Tin cans and tin kitchen utensils are mostly iron, with only a thin coating of tin. Iron so coated with tin is known as *tin plate.*

Tin foil is an alloy of lead and tin, in which there may be more lead than tin. As with other metals, the properties of tin determine its uses. This metal is more active in chemical changes than either lead or copper, but less active than zinc and iron. It is useful as a coating for tin cans and kitchen utensils because it is not attacked by the acids of fruit and vegetable juices.

Tin is scarce and therefore expensive. Only very small deposits have been found in North America, and we must import nearly all that we use. Most of the world's supply of this metal comes from the Malay Peninsula and from the islands of the East Indies. Even in those far-off places there are no really large deposits, and the reserves are rapidly being exhausted. In the United States we consume about 90,000 tons of tin every year. More than one third of this is used for tin plate. Almost all of it is lost because tin cans and similar articles are thrown away after they have been used.

The Precious Metals. Some metals are valued more because they are rare than for any other reason. *Platinum*, for example, is a heavy, hard, chemically inactive metal about as abundant as gold. Most of it comes from Russia and South America. Though platinum is no more beautiful than silver (which is more abundant and therefore less expensive), it is widely used for mounting precious stones largely *because* it is rare and expensive. In the chemical industry platinum is useful in instruments that must stand up against hard physical and chemical wear. But even here certain cheaper alloys are for most purposes just as good.

Silver, though more abundant than platinum, is still one of the so-called precious metals. Most of the world's silver is mined as a by-product of ores whose chief values are in lead, copper, and zinc. This metal is used widely in jewelry, tableware, and coins. Because it is soft and chemically active, it is generally alloyed with other metals which help to overcome these weaknesses.

Exercise. Can you think of some common evidence of the chemical activity of silver?

Gold, which is only about one tenth as abundant as silver, is the traditional badge of wealth. Though this metal has few uses outside of jewelry, art, and coinage, it will probably always be prized above all other metals because it is beautiful and rare.

Exercises. The Mother Lode, the Comstock Lode, the Homestake Mine, Cripple Creek, and the Klondike are places which are rich in the romantic lore of gold. See what you can learn about them in the library.

The Witwatersrand district of South Africa contributes a large part of the world's gold production. Read about this region in an encyclopedia and report on it to your class.

Alloys of the Minor Metals. We have already seen something of the importance of metals other than iron in making alloys of steel. Thousands of alloys have already been made and tested. When need for a metal with particular properties arises, someone tries to supply it. An interesting illustration may be seen in the manufacture of bulbs for electric lights. Because the wire in bulbs is sealed in glass, the rate at which it expands and contracts as it is heated and cooled must be nearly equal to that of glass, or else the glass will break. Platinum is an ideal metal for this purpose, but it is too scarce and too expensive. After many experiments an alloy of nickel and iron was made which worked just as well as platinum.

One of the difficult problems in the manufacture of clocks and watches was the problem of making them keep accurate time both winter and summer. As the pendulum of a clock or the flywheel of a watch expands with warm weather, the machinery tends to run faster. Metal-workers experimented until they found an alloy of nickel and iron, called "invar," that expands and contracts when heated and cooled only one tenth as much as iron. With its help even cheap timepieces can be made that will keep time with accuracy.

Brown Brothers

forbidding coastal mountains of Alaska were only one of the obstacles which men had to overcome in the Klondike Gold Rush of 1898

Progress in the Machine Age. As men work with machinery they discover ways to improve the materials that go into it. The automobile can always use better springs, stronger axles, and longer-wearing paint. The airplane can always use stronger and lighter propellers and metal that will better stand the effects of engine vibration. Railroads, radios, telephones, motion pictures, and other devices make constant demands for improvement.

Though the machines of today seem excellent in comparison with those of even ten years ago, we may expect the machines of ten years from now to be far better than those of today. Among the most successful men of this generation are those who have made things better. So will it probably always be. What part will you play in the changes that are to come?

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Next to wood, iron is the most useful material on earth.

2. Because iron is scattered through practically all the rocks of the earth's crust, the entire crust may be thought of as one great deposit of iron ore.

3. The iron that comes from the blast furnace is known as slag.

4. The difference between pig iron and steel is that the first contains carbon and the second does not.

5. Because copper combines easily with other elements, it is never found as a "free" metal in the earth.

6. Electrolysis is the process of developing an electric current by putting strips of copper and carbon in dilute acid and connecting them by a wire.

7. The chief use of lead is in dry batteries.

8. A storage battery differs from a dry battery in being wet.

9. More zinc is used for storage batteries than for any other purpose.

10. Aluminum is the commonest metal in the crust of the earth and the first one discovered by man.

11. Aluminum is said to have high density because its volume in proportion to its weight is high.

12. America produces nearly all the world's tin.

13. The precious metals are more expensive than other metals because they have many more uses.

14. The minor metals are so called because they have few uses.

Questions for Discussion

1. Do you think that if ways of separating iron from its ores had not been found, some other metal might possibly have formed the basis of our Machine Age? If so, which one?

2. As time goes on, what do you suppose becomes of the iron that rusts away?

3. Should you say that gold is a necessary metal in our modern civilization? Why?

4. Why are alloys important in modern industry?

Things to Do

1. There are five great iron and steel districts in the United States: (1) Pittsburgh; (2) Cleveland, Buffalo, and other cities on Lake Erie; (3) Gary and South Chicago on Lake Michigan; (4) Duluth on Lake Superior; (5) Birmingham, Alabama. It would be interesting to divide the class into five groups, each one to investigate one of these districts. Both the advantages and disadvantages as iron and steel centers should be determined for each district and discussed in class. One of these districts leads the world in production of iron and steel, and for very good reasons. See if you can discover these reasons.

2. Perhaps there is a mine, smelter, or factory in your neighborhood which deals with metals other than iron. If possible, arrange to have your class visit it.

3. Try to find out why gold and silver are so highly prized, and why they are used as standards of value.

4. In this chapter we have not described all the metals with which you may be familiar. What do you know about mercury, for example? Get some mercury and see if you can discover the peculiar properties of this metal.

CHAPTER SIX

What Are the Uses of Mineral Materials Other than Metals?

STONE IN THE WORLD OF TODAY

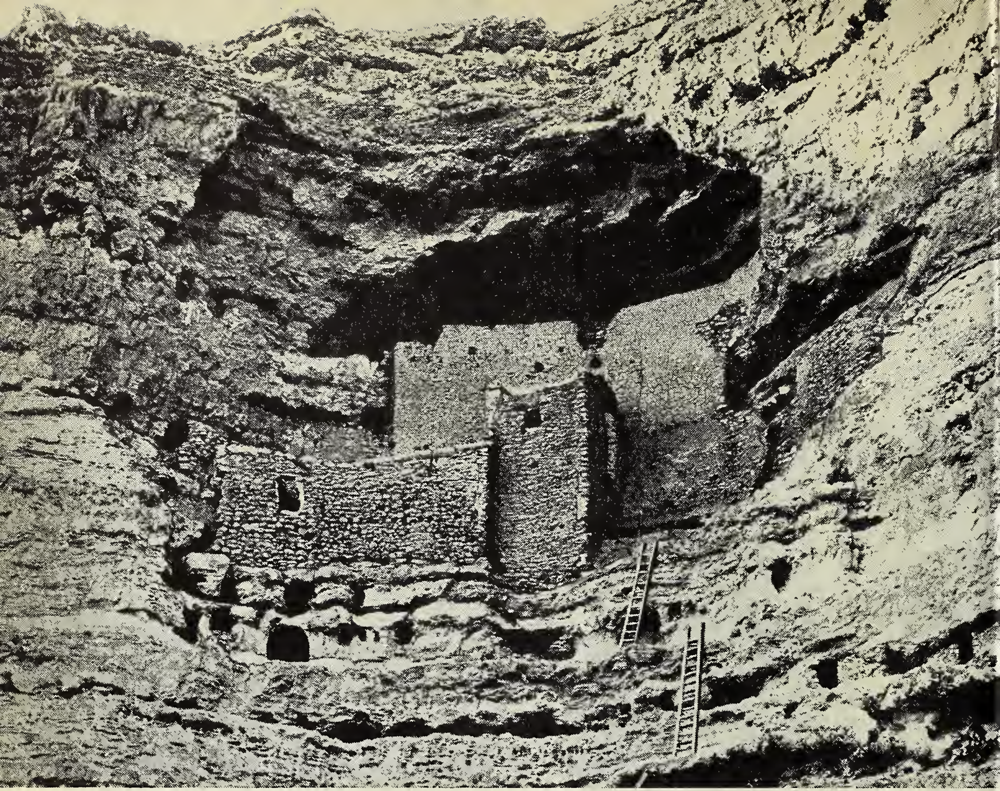
The Everlasting Need of Stone. If you ever visited a large city and stood on the roof of some tall building, you probably marveled at the view below. Such a view is shown on the opposite page. If you think about the materials which have made this scene possible, you soon realize that metals cannot be given all the credit. Indeed, you see very little metal in the picture. What you see is chiefly stone, glass, brick, plaster, and cement.

Man's widespread use of metals has not meant the end of the use of other materials. We still use all the materials that the ancients used. Stone was needed for the buildings of ancient Rome, and it is needed for the buildings of modern Chicago and New York. Modern man makes his buildings higher, and he puts them up more rapidly and more cheaply by using steel frames. He erects them with the aid of metal tools and machines. But such nonmetallic materials as stone, brick, and concrete are still excellent building materials, more enduring than metals and in some cases cheaper. As long as men exist on earth, such materials will undoubtedly be used in human dwellings.

The Advantages of Stone. With a reasonable amount of care, stone buildings will last for thousands of years. An all-metal building, with the same amount of care, would last only a few hundred years at most. The reason for the

Robert Yarnall Richie

The use of stone did not end with the Stone Age



U. S. Forest Service

This stone cliff dwelling in Colorado has long outlived the people who built it

greater durability of stone lies in its resistance to chemical change. Stone, among other things, does not rust in the air. Most stones are made up of the elements calcium, aluminum, and silicon combined with oxygen. Though these elements have a strong chemical attraction for oxygen, this attraction has been satisfied by the time the elements have become part of the stones. Stone, indeed, will not take up any more oxygen than it has at present, even if exposed to the air for a billion years.

Natural Building Stones. The stone used for building is chiefly marble, granite, sandstone, limestone, and slate. All these are common; in places whole mountains are composed of them. Conditions under which the different rocks were formed, however, and the relative ease with which certain kinds may be quarried, have made some deposits more valuable than others. Indiana limestone is one of the most widely used of all natural building stones. It is taken from huge quarries, as shown on page 170. It is softer than marble and can easily be cut and shaped. Many handsome structures are made of this stone in many parts of the country.

Exercise. If there is not one there already, ask your science teacher to try to get a specimen of Indiana limestone for your school laboratory or museum. Examine it carefully with a hand lens or with the low power of a microscope. You may see (as shown on page 171) that it is made of the shells of tiny animals.

The finest marbles and some of the finest granites come from Vermont. Marble is limestone which has been changed in structure, generally by heat and pressure in the rocks. Granite is a speckled rock that was once a hot liquid. Marble is softer than granite and therefore more easily cut and worked. Granite is more durable than marble because it is harder and less easily attacked by acids. Both will take a fine polish and are widely used in monuments and buildings.

A few simple experiments will show you some of the chief differences between marble and granite.

Exercises. Get a piece of marble (or limestone) and a piece of granite and scratch each with the point of a steel knife. Which specimen scratches more easily? Which is harder?

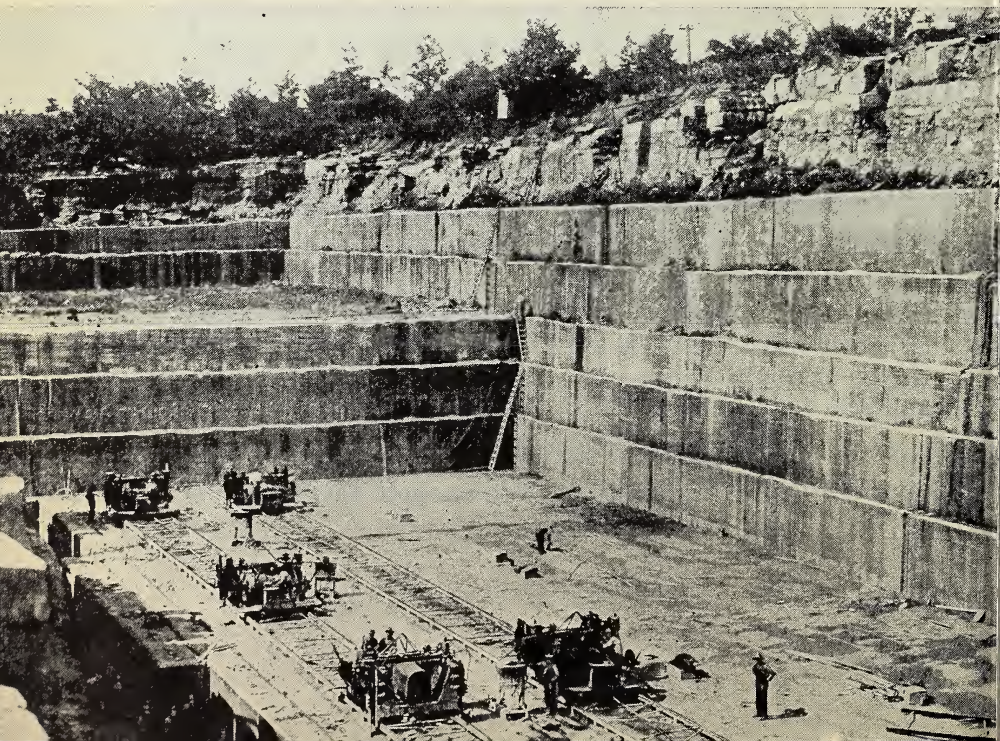
Place some small pieces of marble in one bottle and some pieces of granite in another. Add enough water to cover the pieces and then add some hydrochloric acid. Heat a little. In which bottle do you see evidence of chemical action? What happens to the stone as a result of the action? If limestone is used instead of marble, heating is unnecessary.

Limestone and marble structures are slowly worn away by exposure to the air, especially in regions where there is much coal smoke. Some gases in the smoke form acids when dissolved in rain water, and the faintly acid liquid slowly breaks down the stone.

Other Uses for Stone. The common rocky materials of the earth's crust serve civilization in many ways. Though their chief use is in buildings, they are very valuable in road-making and in the manufacture of concrete. Ordinary loose sand is useful not only in making mortar and concrete, but in making glass, abrasives (polishing materials), and the

The thick flat layers of Indiana limestone furnish an excellent building stone

Indiana Limestone Corporation



Buffalo Museum of Science

shells in this specimen of Indiana limestone give proof of its origin in an ancient sea

molds which are used in iron foundries. Clay is useful in the manufacture of bricks, tiles, sewer pipes, and pottery.

Limestone is perhaps the most widely used of all rocks. In addition to its use in buildings and roads, it is needed to release iron and other metals from their ores. It is used in the manufacture of sugar and glass, and in agriculture as a cure for sour soils. It is the chief source of the lime used in mortar, in the tanning of hides, and in many chemical industries. The demand for this common stone is so great that the amount consumed each year nearly equals that of iron ore.

Exercise. Study your school building and make a list of the different common earth materials that went into its construction. See which member of the class can identify the greatest variety of materials.

ARTIFICIAL BUILDING STONES

Clay as a Building Stone. Artificial stones of several varieties are widely used in building. *Brick* is a well-known type of such stone. Brickmaking goes back to very early times. Excavations of ancient cities have uncovered brick constructions which are probably six thousand years old. In the simplest method of brickmaking, common clay and water are mixed into a paste. The paste is put into wooden molds and allowed to harden by drying in the sun. Long before the Christian Era, however, men learned to harden bricks by burning them in kilns, as shown below.

Brick houses are sturdy, fireproof, warm in winter and cool in summer. *Fire-clay bricks* are made of heat-resisting clays for use in furnaces. Hollow *tiles* made of clay in the manner of bricks make excellent covers for roofs; flat tiles make durable floors and walls. *Pottery* and *chinaware* are also made in much the same manner, but they require special kinds of clays.

Exercises. Get some common clay and see if you can make it into a brick. Your mother may allow you to use the oven to help you speed the process.

List all the different kinds of objects in use in your home which are made of clay.

This man is laying bricks in a kiln where they will be hardened by fire

Sawders

Mortar. Mortar is an artificial building material which is made of lime, water, and sand. The manufacturing process begins with limestone, which is a compound of calcium, carbon, and oxygen known chemically as calcium carbonate. When heated this stone breaks down, forming calcium oxide (lime) and the gas carbon dioxide.

Exercise. Get a sample of lime from a bricklayer or a plasterer. He will probably call it "quicklime," but lime and quicklime are the same thing. Place a small amount in a beaker and slowly add enough water to cover the lime. You immediately see evidence of chemical action. Heat is produced, and the appearance of the lime changes. After chemical action has ceased, there remains a white pasty mass which is commonly known as slaked lime. This is lime combined with water.

Next mix the pasty slaked lime with sand. The product is mortar. Spread a layer of fresh mortar about half an inch thick on a board and observe it through a period of a few days. Describe the changes.

When slaked lime is exposed to air, it loses its water and takes on carbon dioxide from the air, thus slowly turning back into calcium carbonate. While doing this it gets harder and harder, a change which is known as *setting*. Sand is used in mortar to keep the lime from becoming absolutely solid. In this way the carbon dioxide may penetrate to the interior and harden the entire mass. The setting of mortar may continue for years and possibly for centuries.

Mortar is one of the most widely used artificial building materials

Galloway

Mortar is used everywhere for binding bricks together. The bricks are laid in the mortar while it is soft. After it has been exposed to the air, the mortar dries and hardens. This artificial stone is also used as plaster for the walls of houses.

Cement. Cement is in some respects similar to mortar. It is made by heating a mixture of limestone and clay. These materials are dried and powdered, mixed, and placed in a furnace. The mixture is heated until it just begins to melt and run together. As it is heated, water and carbon dioxide are driven out. The materials which are left unite in a mixture of rather complicated chemical compounds which is known as cement.

A most important difference between cement and mortar is that *cement will harden (or set) under water, and mortar will not.* The chemical change that goes on when cement sets is, indeed, due to chemical action with water; air has no necessary part in it. Enormous quantities of cement are used, therefore, for building under water. The setting of cement goes on slowly and may continue for years, as in the case of mortar. Its strength increases during all the time the cement is setting.

Concrete. One of the main uses for cement is in building concrete highways. *Concrete is a mixture of cement with sand and stone.* During the years since the automobile has come into common use, thousands of miles of concrete highways have been built.

Other important uses of concrete are for building tunnels and dams. The Boulder Dam, in the Boulder Canyon of the Colorado River, is one of the great engineering achievements of modern times. It is 727 feet high, and its length

Sawders

is view of Boulder Dam is a testimonial
to the importance of concrete in the modern world

along the crest is 1282 feet. Some 4,500,000 cubic yards of concrete (about 10,000,000 tons) were used in its construction. This mighty barrier holds back a vast reservoir, or storage basin, of water, sufficient to cover 30,000,000 acres of land to a depth of 1 foot. This is an area almost equal in size to the state of New York.

Water from the reservoir is used to irrigate the desert lands of neighboring regions and to generate electricity. There is enough water behind Boulder Dam to generate nearly two million horsepower. By way of comparison, the same amount of power released through electric locomotives would be sufficient to keep six hundred heavy passenger trains on the move.

The Grand Coulee Dam, in the Columbia River in Washington, is even larger. The water flowing over it will be sufficient to generate more than two and one half million horsepower. With these two dams in operation the total water power available in the United States will be increased more than four million horsepower—some 25 per cent.

Without doubt the future will see many similar pieces of construction. At Minneapolis the Mississippi River is some eight hundred feet above sea level. In time of flood it flows as a raging torrent, overflowing its banks and spreading ruin far and wide. Engineers believe that part of the answer to the problem of the Mississippi is dams. They are building more dams along the course of the river, like the ones which now exist at St. Paul, Minnesota, and at Keokuk, Iowa. Such dams hold back the floods and save thousands of acres of farm lands from damage. Besides, each dam is a source of water power that can be converted into electrical energy.

What does it cost to do such mighty work? It might be wiser to ask what it costs *not* to do it. Most of the construction work is done with iron and concrete, and we have plenty of both. Iron ore is of no use so long as it remains in the ground; neither is limestone or clay. Labor is required, but there is no lack of men and machines for that. Engineering science may greatly help to free us from the fear of hunger and ruin. It may help us to use the abundant natural resources of our nation for the common good.

Exercise. Ask your teacher to write to your senator and ask him for information concerning some of the great dams which the government is now building.

THE USES OF GLASS

What Glass Is. If we return to the roof of the skyscraper on which we began this chapter, we may see thousands of windows glistening in the sun. At night many of these windows themselves become little suns which shine with the light of countless electric bulbs. Either day or night we are struck by the beauty of the lighting, a beauty made possible by one of man's cleverest inventions: glass. This substance is not only beautiful but endlessly useful in modern civilization.

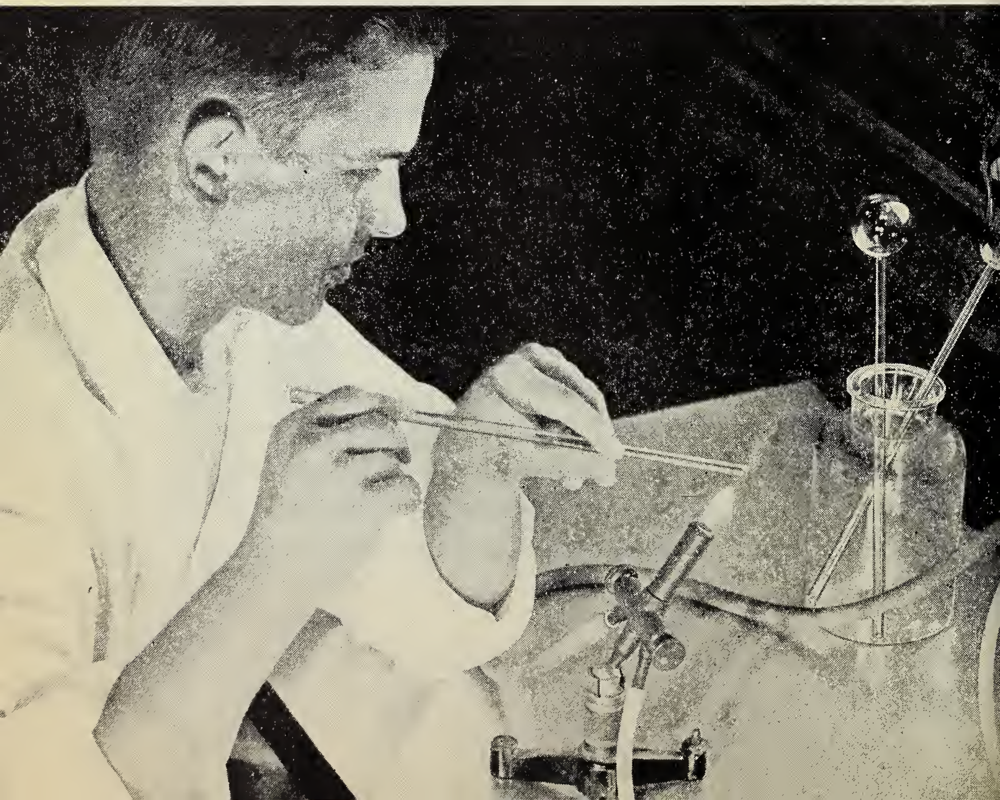
Glass is made from silica in the form of fine sand, sodium carbonate, calcium carbonate in the form of limestone, and a few other substances. Nearly pure materials must be used for the manufacture of clear glass. Fortunately, there are many natural deposits of sand that are nearly pure silica, and many deposits of limestone that are nearly pure calcium carbonate. Sodium carbonate is a manufactured product, and its purity can be controlled at the factory.

If we could follow the changes that take place in these substances as they are fed into a large furnace at a modern glassmaking plant, we should first see the mixture change to liquid. Sodium carbonate and calcium carbonate melt at about 850° centigrade. Silica dissolves in the hot liquid somewhat as salt dissolves in water. The liquid is heated to a temperature of about 1260° C. Chemical changes take place in which carbon dioxide is released as gas. The liquid that remains may be as clear as pure water. As it cools, it stiffens.

Glass-Blowing. While glass is still hot and soft it may be molded to any shape, as a simple experiment will show.

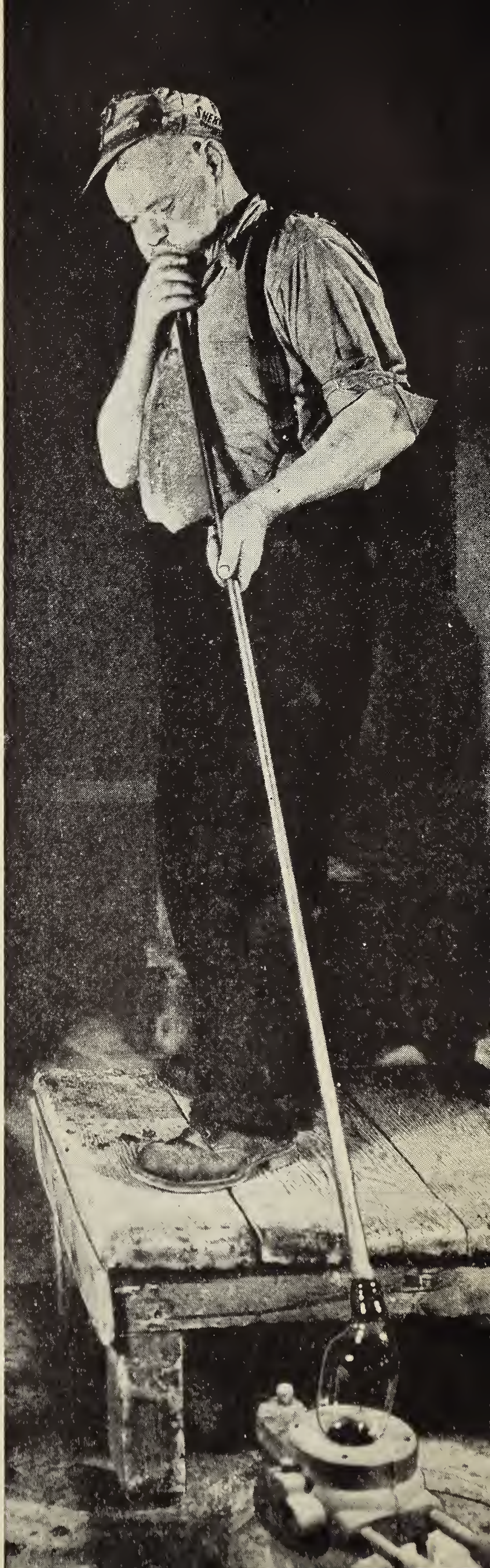
Exercise. How to shape hot glass: Get a piece of glass tubing about a foot long. The ends of the tubing will have sharp edges, which you may "polish" with fire. Hold one end of the tubing in a gas flame until the glass is barely red. After the glass has cooled, run your finger over the edge and you will see that the sharpness is

This boy is making a simple experiment in glass-blowing



gone. Next hold the other end of the tubing in the flame. Turn it slowly until the glass melts and the end of the tube closes. Then place the cool end of the tube in your mouth and blow. Blow a glass bubble (similar to a soap bubble) on the closed end of the tube, as shown on the opposite page.

A good deal of skill is required to shape hot glass into the elaborate objects with which we are all familiar. Years of practice are necessary for the training of a good glass-blower. Not many years ago glass-blowing was all done by hand, or rather by lungs. The glass-blower worked with a long metal pipe, as shown in the photograph at the right. He dipped one end of the pipe into the molten glass and pulled out a large drop of just the right size for the object he intended to make. Then he blew a "bubble" of glass on the end of the pipe, just as you did



Galloway

Compressed air in mechanical lungs has thinned the ranks of the old-fashioned glass-blowers on the end of your tubing. Next he shaped it by blowing and whirling the rod as the glass cooled.

Today nearly all glass-blowing is done by machines which are run by compressed air. The new process is enormously faster than the old one. In the old days an expert bottle-blower could turn out bottles at the rate of about one hundred per day. Now a single machine may turn out as many as fifty thousand bottles per day.

The bulbs for electric lights are made with automatic machines. One machine can make over four hundred bulbs a minute. That is almost half a million bulbs per day. Four or five such machines, tended by a few men, make all the light bulbs that are used by all the people of the United States and Canada.

How Glass Is Annealed. If you were to take a glass bottle directly from the blowing machine into a room of normal temperature, you would find that it would almost surely crack. The reason for this is that glass cools unevenly, and some parts of it are under mechanical stress. As soon as bottles are blown, therefore, they are moved into what is called an annealing chamber.

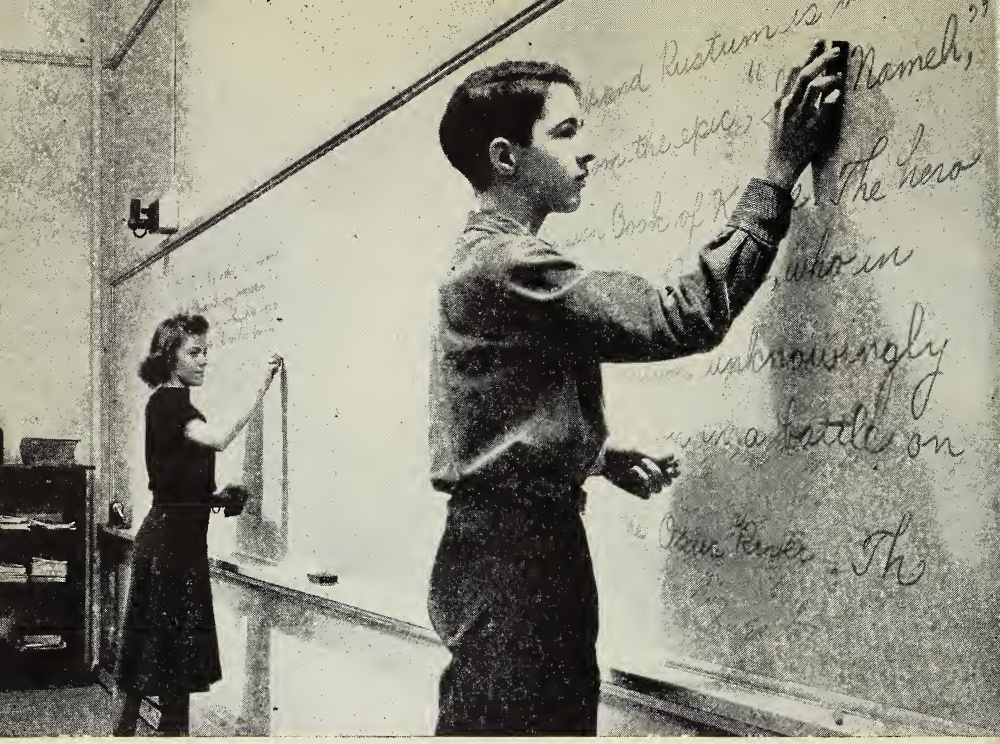
The temperature at one end of the chamber is about 600° C. The bottles are carried along slowly, cooling as they are moved. A period of about two weeks is used to cool heavy bottles. Thinner glass, like light bulbs, may be cooled in a few hours. The long period of cooling permits the glass to flow a little and thus slowly to relieve the mechanical stress which, if relieved suddenly, would break the glass. This process is called annealing.

Window Glass. Until very recently glass for windows was first blown into great cylinders, thirty or forty feet in length

The Pittsburgh Plate Glass Company

sandy material which this man is shoving into a melting tank will be changed into molten glass

This craftsman has trimmed off the uneven edges of a large sheet of glass



Sawders

Here is one of the most modern uses for plate glass

but not more than three feet in diameter. After the glass cooled, a hot iron point was drawn quickly around the closed ends of the cylinders. The heat from the iron caused the glass to break in a clean, straight line. In a similar manner the long cylinders were cracked lengthwise.

Each cracked cylinder was placed in a furnace. As the glass softened, the cylinder opened and the glass was spread flat on the surface of a table. After the sheet had cooled, it was cut into sizes suitable for window glass. This process made glass which generally contained areas through which objects appeared out of shape.

Exercise. Examine the window glass in your classroom. Are there areas through which objects appear out of shape?

Today most window glass is made by a different method. Raw materials are heated in a melting tank to 2730° F., as shown on page 181. The molten glass is then drawn upward through rollers much as clothes are drawn through a wringer, and pressed into a flat sheet as it cools (see page 181).

Plate Glass. The best glass for show windows and windshields is called plate glass. It is made with more care than ordinary window glass and is therefore more expensive. The liquid glass is poured out on a flat surface and pressed between steel rollers. As it cools, it forms a slab of nearly uniform thickness. Any irregularities are then carefully removed by grinding. The finished slab is so nearly uniform in thickness that it does not change the appearance of objects seen through it. You are aware of the difference between plate glass and ordinary window glass when you compare the plate glass which is used in show windows of fine stores with the glass in the windows of residences.

Cut Glass. Glass used for cut-glass dishes is not the same in composition as window glass. Instead of limestone, lead oxide is used. This lead glass has a more brilliant sparkle than ordinary lime glass, and it is less easily broken. The finest cut glass is expensive because of the great amount of handwork that must go into its manufacture.

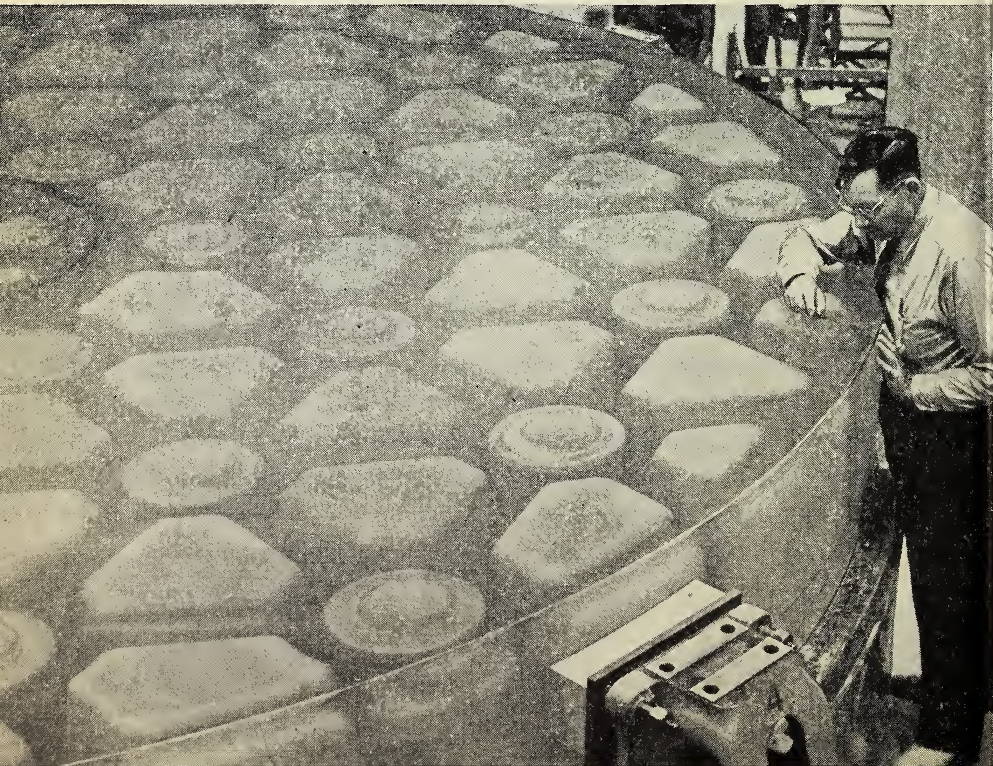
In making cut glass, the melted glass is pressed into a mold of any desired shape. It comes from the mold as a smooth glass dish. The designs are then cut into the glass by grinding and polishing. For cheaper cut glass the pattern is shaped in the mold so that when the glass comes from the mold it has the pattern impressed in it. The process of cutting is thereby reduced merely to grinding the edges and polishing the surfaces.

Glass for Telescopes. A striking example of great achievement in glassmaking is the pouring of the glass for the mirror of the 200-inch reflecting telescope on Mount Palomar in California. This mirror is made of a glass that expands and contracts so little during changes in temperature that the likelihood of its breaking is small. About one hundred tons of glass were melted in one enormous furnace. From this the molten glass was dipped and poured into a mold. The cooling, or annealing, of this mirror was very carefully controlled. The entire casting process took about ten months.

After the twenty-ton chunk of glass was cast, many more months were consumed in grinding it to exceedingly precise measurements. An error of more than two-millionths of an inch would have seriously damaged the great mirror!

The mirror for the 200-inch reflecting telescope on Mount Palomar is a mod triumph in glassmaking. Hollows molded into the underside of the mirror to red its weight produce the geometric figures which appear through the surface of the gl

O. K. Harter



Marcus H. Brown, who successfully accomplished this delicate task, is shown on page 184 examining his masterpiece.

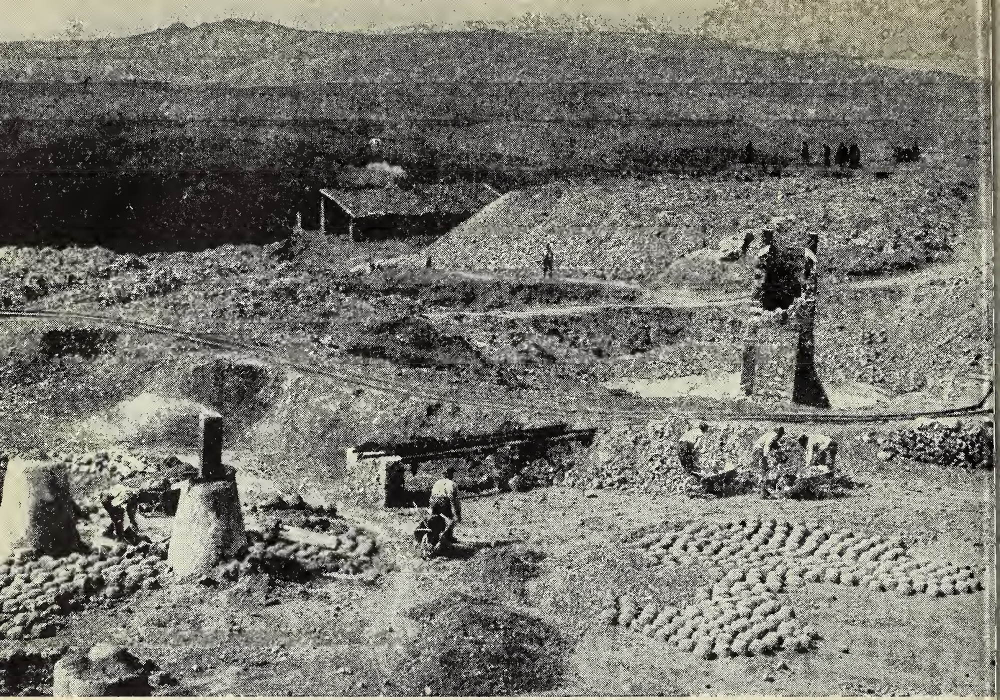
Fused Quartz Glass. Melted, or fused, quartz (which is almost pure silica) may be used for glass. It differs from ordinary glass in that it is transparent to the visible rays of the sun and also to the invisible ultraviolet rays (which do not pass through ordinary glass). Ultraviolet light is important for health, and for this reason quartz glass is sometimes used in the "sunrooms" of hospitals. Light coming through quartz glass produces nearly the same healthful effect on the body as direct sunlight.

Fused quartz expands and contracts so little with changes in temperature that it may be heated red-hot and plunged into cold water without danger of breaking. It is thus fine for cooking utensils. It is clearer than ordinary glass and less fragile, but unfortunately it is too expensive for general use.

Exercise. A special glass called pyrex is used for cooking utensils. See what you can find out about this glass; how it is made and why it stands up under heat.

OTHER USEFUL MINERALS

Sulfur. Not all the useful nonmetallic minerals are used chiefly for building purposes. Probably no mineral has a greater variety of uses than sulfur. It is used in the manufacture of sulfuric acid, and this is used in enormous quantities in chemical industries. Sulfur is also used in matches, gunpowder, and fireworks. One of the most important uses is in the rubber industry. When sulfur is added to rubber, the rubber becomes much tougher, less apt to crack in the cold, and less apt to melt in the heat.



Sawders

In Sicily sulfur is mined by men in underground workings and then heated in kilns to remove the impurit

Until 1903 the world depended very largely on the rich sulfur deposits of Sicily. Since then Texas and Louisiana have become the largest producers. Owing to the brilliant invention of Dr. Herman Frasch, sulfur that lies buried five hundred to fifteen hundred feet below the surface can be easily and cheaply mined. Instead of mining it through tunnels and other costly underground workings, the Frasch process merely introduces hot water and compressed air into the deposits through pipes. The sulfur is thereby melted and forced through other pipes to the surface.

The photographs above and on page 187 show the old-fashioned and the modern methods of mining this mineral. No greater contrast exists anywhere in the world of mining.

Exercise. Read in an encyclopedia about the Frasch process for mining sulfur, and report on it to your class.

Nitrogen and Nitrogen Compounds. Everybody knows that growing plants rob the soil of mineral material. A ton of wheat is said to take 47 pounds of nitrogen, 18 pounds of phosphates, and 12 pounds of potash from the earth. It is easy to see that these mineral materials must be put back into farm lands if they are to go on producing crops.

One way of putting them back is by treating the soil with fertilizers which are rich in the needed elements. Nitrogen is an element that tends to disappear from soil that has been extensively tilled. Chile contains the only extensive deposits of rich nitrogen compounds in the world. These Chilean nitrates, as the compounds are called, have been the chief source of nitrogen in commercial fertilizers for many years. More recently chemists have discovered a cheap method of extracting nitrogen from the air, which has reduced the need for natural nitrates.

ouisiana and Texas underground sulfur is melted by hot water and forced to the ace through pipes (see inset). There it hardens into a chemically pure deposit

Texas Gulf Sulfur Company

American Agricultural Chemical Co.

The soft phosphate rock of Florida is broken up by strong jets of water (hydraulic mini

Ammonia is a compound of nitrogen and hydrogen which, when combined with sulfuric acid, gives rise to a soluble nitrogen compound that the roots of plants can use. Today nearly half the nitrogen compounds used as fertilizers in this country come from Chile and nearly half are manufactured from ammonia. A very small percentage is made from the air.

Phosphates. Phosphorus, as every farmer knows, is absolutely necessary to the health of growing things. Bones are rich in the compounds of this element (phosphates) and are used as fertilizers throughout the world. Waste from slaughterhouses and fish-packing plants is also rich in phosphates. Do you remember the story of the Indians teaching the Pilgrims to place a fish in each hill of corn?

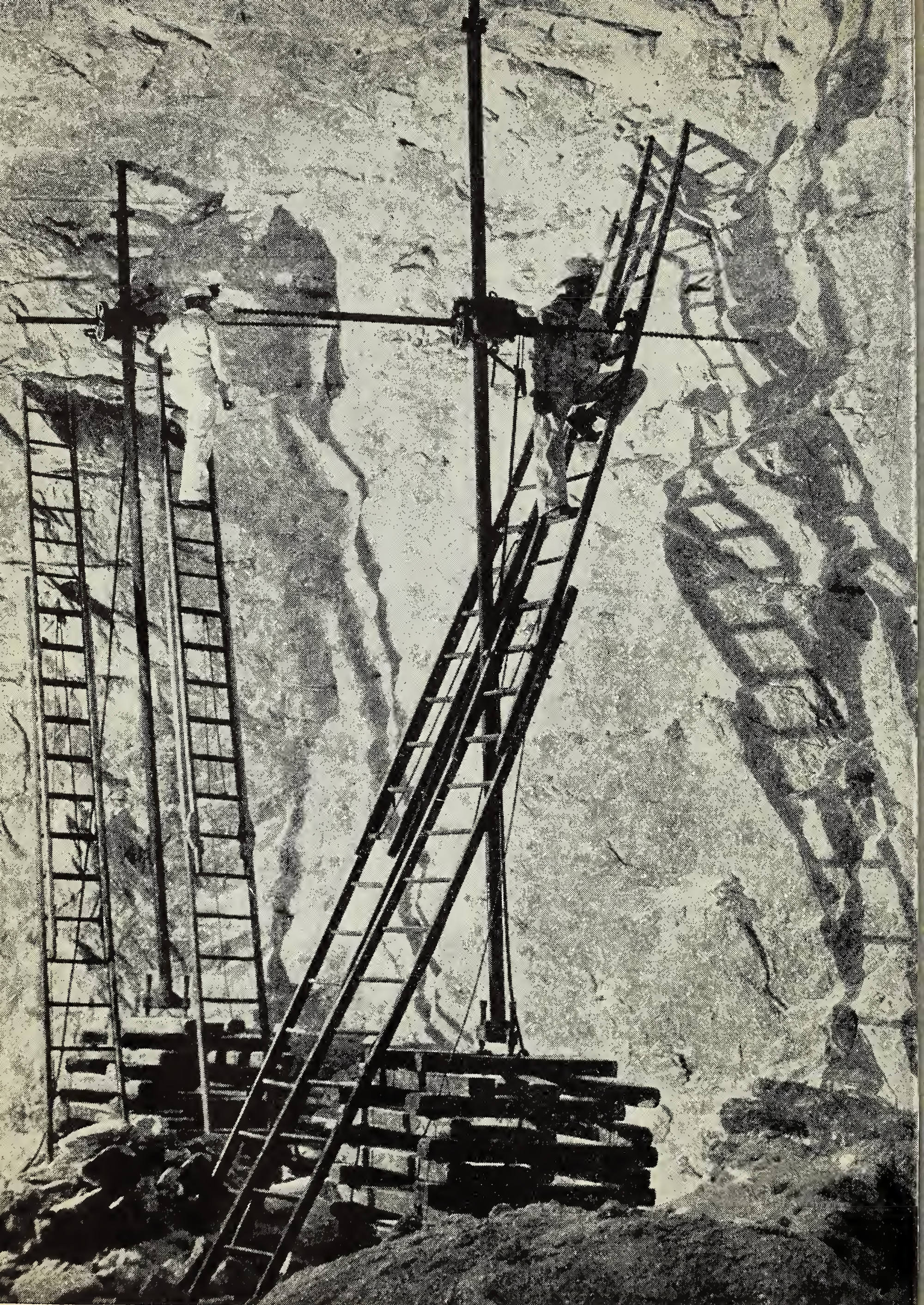
The Indians didn't know the name of phosphate, but they knew its value as a fertilizer.

On the islands off the coast of Peru birds flock by the millions, and their droppings have piled up to a thickness of more than thirty feet. These *guano* deposits, as they are called, have been a rich source of commercial phosphates. Much richer sources are the phosphate rocks of Florida and the Far West. They are made up very largely of the skeletons of extinct animals and are the richest reserves of phosphates in the world. The photograph on the opposite page shows mining operations on one of these deposits in Florida.

Potash. Potassium is another element which crops must have. Unfortunately, most natural compounds of potassium (potash) are insoluble, and plants can use only the soluble variety. The only large deposits of soluble potash now in use are at Stassfurt, Germany, and in Alsace, a part of conquered France. Rich deposits of soluble potash have recently been discovered deep below the surface of Texas and New Mexico. Now that the foreign sources (which in the past have supplied nearly all our potash) are cut off from us, we must turn to these relatively undeveloped reserves.

Exercise. Look up the rich potash deposits at Stassfurt, Germany, and make a report on them to your class. How long will they last at the present rate of use? Compare the German deposits with the American deposits near Carlsbad, New Mexico.

Salt. Not even iron or copper are more important than the lowly mineral, salt. Both animals and men must have it or die. Animals have been known to travel long distances



Rittase

These men are mining a giant salt dome hundreds of feet below the surface of Louisia to find it, and men have been known to use it as a standard of wealth in certain parts of Africa where it is scarce. Salt is used everywhere for seasoning and preserving food. It is also used widely in the manufacture of soda and other chemical products.

Vast deposits of pure salt occur and are extensively mined in many places throughout the world. Evaporating desert lakes supply much commercial salt, as does the evaporation of sea water in artificial lagoons. The most remarkable salt reserves in the world are the giant salt domes of Louisiana, Texas, and Germany. Pushed up from some hidden source below the surface, salt has accumulated in these domes to a thickness of more than a mile. If the need should ever come, they could supply the whole world with salt. (See opposite page.)

Exercise. Look up and report on the salt domes of Texas or Louisiana. Has any considerable start been made toward the marketing of this salt?

Minor Nonmetallic Minerals. There are a host of lesser nonmetallic minerals in use in the modern world. There is gypsum, for example, which is used in the manufacture of plaster of Paris. There is graphite (chiefly carbon), which is not at all like the metal lead, but which makes up the so-called "lead" in pencils. There is borax, which is used for cleansing powder; barite, for paint; mica, for a variety of electrical purposes; asbestos, for fireproofing and insulating. There are many others too numerous to name. All these help to swell the ranks of nonmetallic minerals which are part of our modern life. Modern life, indeed, would be quite impossible without them.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Modern buildings are made chiefly of metal rather than stone because metal is both cheaper and more lasting than stone.

2. Limestone and marble are better building stones than granite because they are less easily attacked by the acids in air and water.

3. Granite is a better building stone than limestone and marble because it is softer and more easily cut and shaped.

4. Common clay, which is worthless today, is likely to be put to use as science advances.

5. The chief difference between cement and mortar is that mortar will harden under water and cement will not.

6. Concrete is just another name for cement.

7. Next to iron, concrete is the most abundant material used in the construction of dams.

8. The human lung is still the most widely used tool in the manufacture of glass bottles.

9. The process of annealing rids glass of its air bubbles.

10. The chief difference between ordinary glass and plate glass is that plate glass is much purer.

11. Sicily is the largest producer of sulfur.

12. If the foreign sources of the fertilizer minerals were cut off, American farmers would be put out of business.

13. Most commercial salt comes from the giant salt domes of Texas and Louisiana.

14. Plaster of Paris is a pure form of mortar which is used in the treatment of broken limbs.

Questions for Discussion

1. Why do you think ancient peoples, such as the Greeks, used marble more than other stones for building purposes?

2. What relationships do you think there are between the use of iron and the use of concrete? Consider such an industry as the building industry.

3. Do you think it likely that fused quartz will in the future entirely replace ordinary glass?

Things to Do

1. Make a study of changes that have taken place in the building industry as the result of new materials. Could the modern skyscraper have been built one hundred years ago?

2. Secure some samples of different kinds of stone, such as flint, sandstone, granite, and marble. Test them for hardness with a steel knife and a piece of glass. Which stones will the knife scratch? Which stones will scratch the glass? Which stone is the hardest and which the softest? You may also test the strength of different stones with a hammer and with dilute hydrochloric acid.

3. Make a study of the materials in the buildings of your town or city and prepare a report for your class. You might arrange your findings under the following headings: Natural Building Stones; Artificial Building Stones; Glass.

4. You can find out about some of the properties of glass for yourself. Heat and bend some glass tubing, blow glass bubbles as described in the text, or make a glass pen that will write.

CHAPTER SEVEN

What Is the Nature of Fuels?

THE STORY OF COAL

The Importance of Fuels. In the earlier chapters of this unit we studied the mineral materials that have gone into the building of the modern world. In this chapter we shall study the mineral materials that run the world. Stone and metal are not enough to create a machine civilization such as ours. The machinery is useless unless it is fed the energy that makes it go.

Most of the energy that runs the machinery of the modern world comes in the form of heat from the burning of coal, gas, and petroleum. Coal furnishes heat to countless buildings and turns the wheels of countless factories, power plants, and railroads. Gas is used in a million places for cooking, heating, and cooling. Petroleum runs our automobiles, heats many of our buildings, and moves many of our ships and trains. These three heat-yielding mineral materials are called fuels. They are among the most important substances on earth, because without them (or some similar materials to take their place) civilization as we know it would cease to exist.

Old King Coal. Old King Cole of the nursery jingle was a jolly old soul, but he was a very little king when compared with Old King Coal. Coal is undoubtedly the king of fuels and undoubtedly very old. Though petroleum is challenging the leadership of coal in the industrial world today, coal is still king, as the graph on page 196 will show.

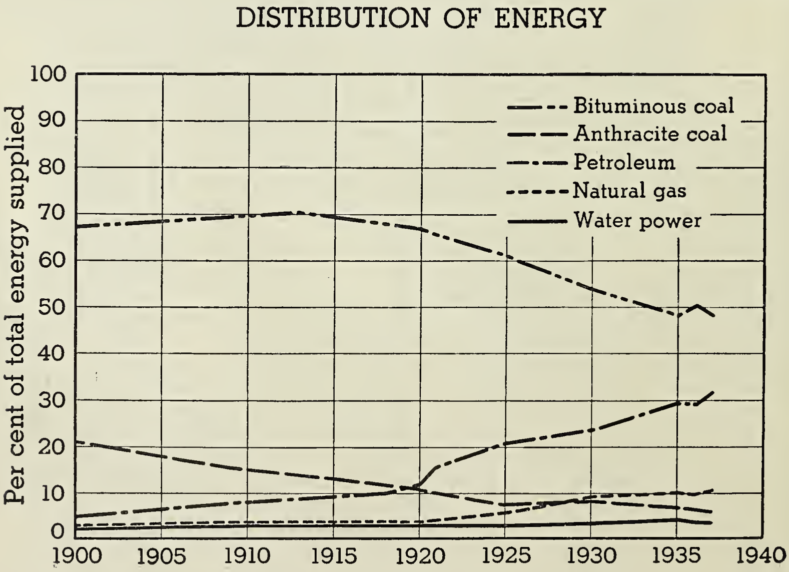
Galloway

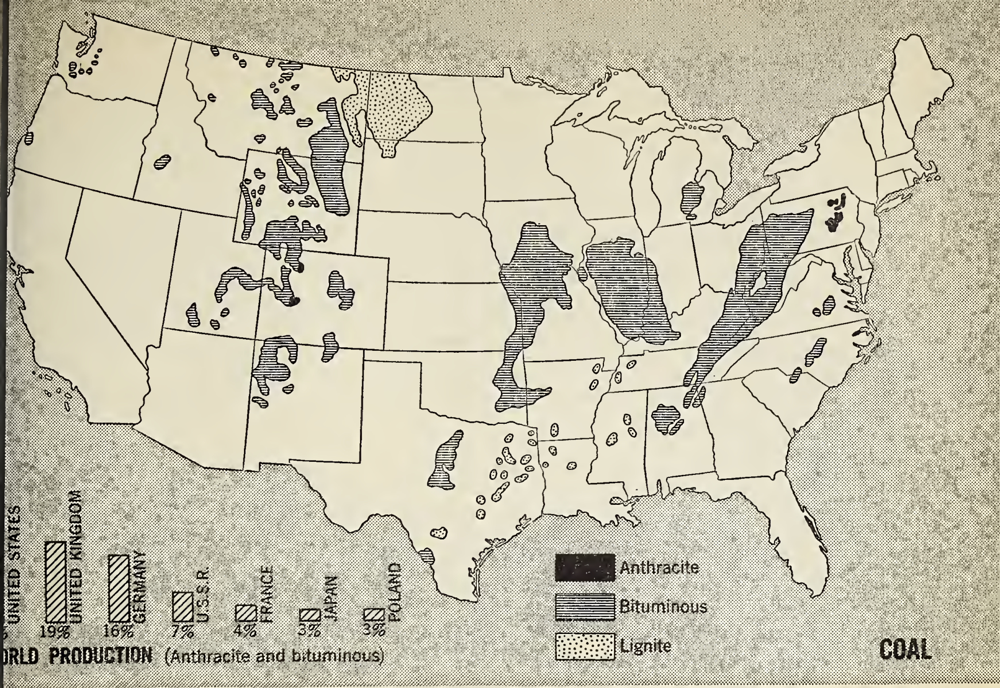
Fuels make the modern world go round

The Origin of Coal. Long ages ago there were times when the climate of the earth was milder than now. At these times great swamps took form on the lands and strange plants grew thick and tall in the warm, shallow waters. As the ages passed, the dead bodies of these plants piled up on the bottom of the swamps. Bacteria drew oxygen and hydrogen from the decaying vegetation, but allowed the carbon to be buried under sand and mud which the rivers brought in.

As time went on, the imprisoned plant remains were squeezed together and hardened into seams of coal. The sand and mud were hardened into layers of rock. Being rich in carbon, coal is rich in energy that can be released by burning—the energy of sunshine that fell upon the earth many millions of years ago.

This graph shows the relative importance of the various energy-producing minerals





This map tells the story of the location and production of coal in the United States

The Discovery of Coal. Man is not generally slow to make use of his blessings, but he was slow to recognize the value of coal. The ancients knew that coal would burn, but they preferred wood as a fuel. Even as late as the seventeenth century there were laws to prohibit the use of coal because it was dirty. Not until the steam engine was invented did coal really rise to importance in modern civilization. By 1835 the railroads began to use it in place of wood. From then on its importance increased, until today it is the chief source of power throughout the civilized world.

The Types of Coal. There are many different kinds of coal. Since carbon is the substance that burns in coal, it is used as the basis for classifying coals. In the United States vast deposits of low-grade coal occur in the southern and north-central states. These are relatively low in carbon and therefore relatively poor as fuels. They are known as *lignite* coal and are still very largely unused.

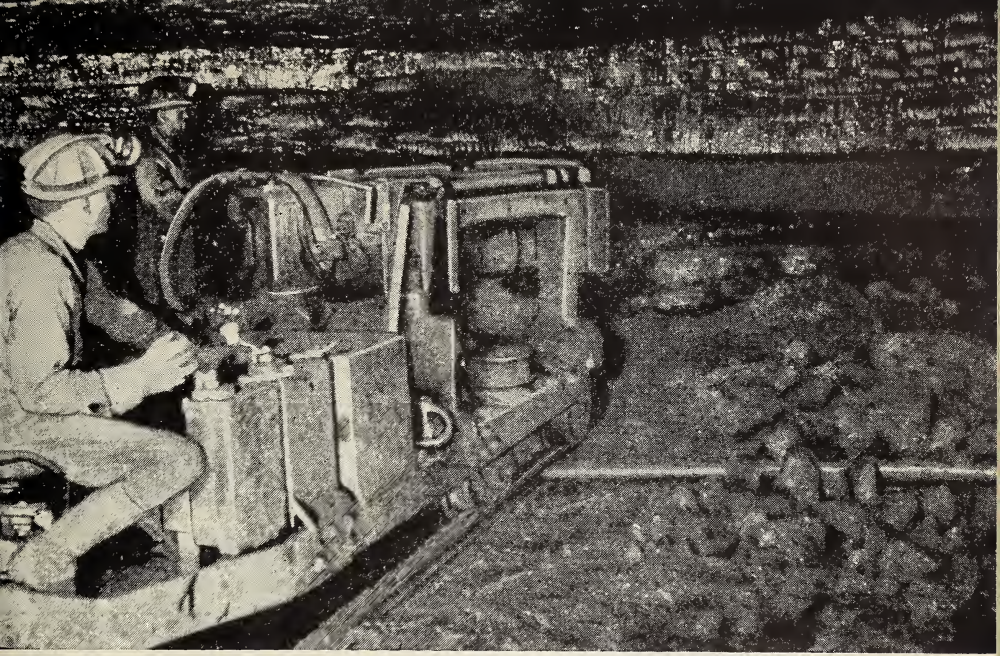
Higher in carbon are the vast deposits of *bituminous*, or "soft," coal, which are scattered widely from Washington to Alabama and from Montana to Texas. This variety of coal is much the most abundant of all the types and much the most important source of power, as we saw in the graph on page 196.

As the gaseous elements of the original vegetation were squeezed out of coal during the process of formation, the coal tended to get harder and harder. In *anthracite*, or "hard coal," this squeezing process has gone much farther than in any other type. Anthracite is the highest in carbon, the hardest, and the most expensive of all the coal types.

There are other kinds of coal, but they can be grouped in a general way under the three kinds described above. In the map on page 197 you will see how these types are distributed in the rocks of this country and how rich a storehouse of coal the United States is, as compared with other countries.

Some coal is mined at the surface of the earth by electric shovels

Coal Age



Coal Age

Most coal is mined in caverns deep below the surface of the earth

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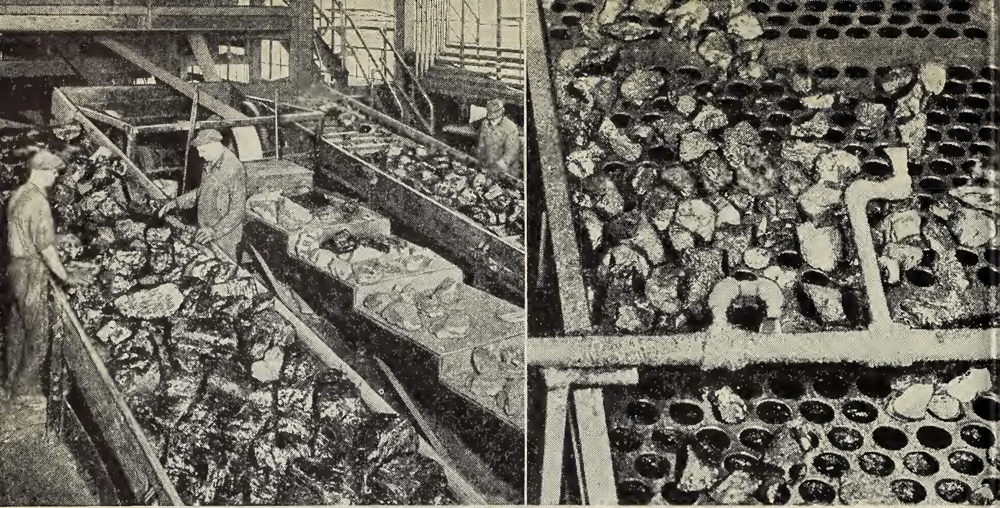
Exercise. Get samples of "soft" and "hard" coal from a local coaldealer. Compare their hardness (by scratching each with a knife), their luster (shine), their fracture (how they break when struck with a hammer), their weight, and their streak (the color and amount of dust that comes off when the specimens are rubbed on a piece of white porcelain). Do this for two or three specimens of each variety of coal and keep a record of your findings. Are all the specimens of each variety alike or nearly alike in physical properties? What would you say are the chief ways in which "soft coal" may be distinguished from "hard coal"?

How Coal Is Mined. Coal occurs in layers or seams, a few inches to many feet in thickness. Some seams of coal run so close to the surface of the earth that they can be mined by electric shovels, as shown on page 198. The larger shovel in the background is removing the worthless rock from the


Anthracite Industries

The men at the left are separating coal from chunks of worthless rock.
The screen at the right is used to separate smaller from larger pieces of c

top of a coal seam. The smaller shovel is loading coal into trucks after workmen have blasted it into smaller pieces.

Most coal mines are deep in the rocks of the earth. Vertical shafts with elevators connect horizontal tunnels at different levels, very much as the elevator shafts in a hotel connect the hallways of the various floors. Leading off from the hallways on the various floors of a hotel are the rooms which the guests occupy. Leading off from the tunnels on the various levels of a coal mine are the roomlike caves where the coal is dug.

The illustration on page 199 shows a miner operating an electric coal-cutting machine in such a cavern. By means of a moving chain in the nose of the machine a groove is cut along the bottom of the coal seam. Miners then drill holes in the coal above the groove, place dynamite in the holes, retreat to a safe distance, and discharge the dynamite by an electrically operated cap. The coal falls to the floor and is then loaded on small electric cars ("electric mules") and lifted to the surface of the earth.

The coal is then dumped on a slowly moving conveyer belt while workmen pick out the worthless chunks of rock generally mixed with it. This process is shown on the opposite page. Next the coal is passed over a vibrating chute which sorts the coal by shaking the pieces through holes of different sizes (see opposite page). Finally the coal is washed, dumped into coal cars, and carried to a waiting world.

Exercise. Look up in an encyclopedia the various uses of the different kinds of coal and report your findings in class.

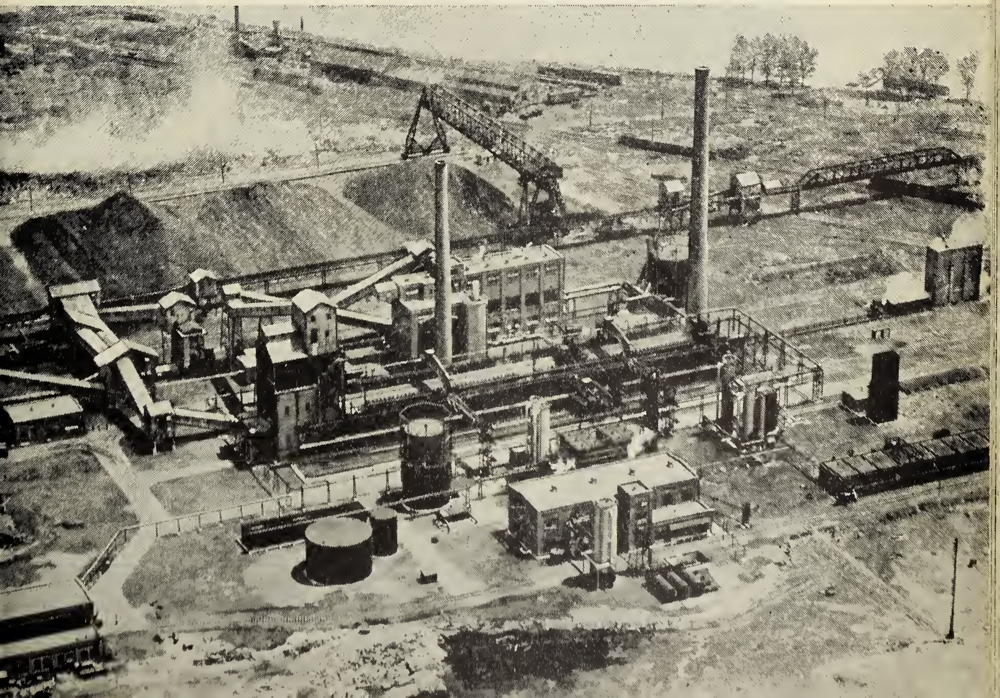
THE STORY OF GAS

Early Uses of Coal Gas. When soft coal is heated in the presence of air it becomes a hot, glowing heap which in time breaks down into cold, gray *ash*. When soft coal is heated, with the air excluded, it turns partly into a colorless inflammable gas known as *coal gas* and partly into a porous dark-gray solid called *coke*.

Toward the close of the eighteenth century a Scotchman, William Murdoch, invented a simple machine for the manu-

Here is a modern plant for the manufacture of gas from coal

Aero Service Corporation and Philadelphia Coke Company



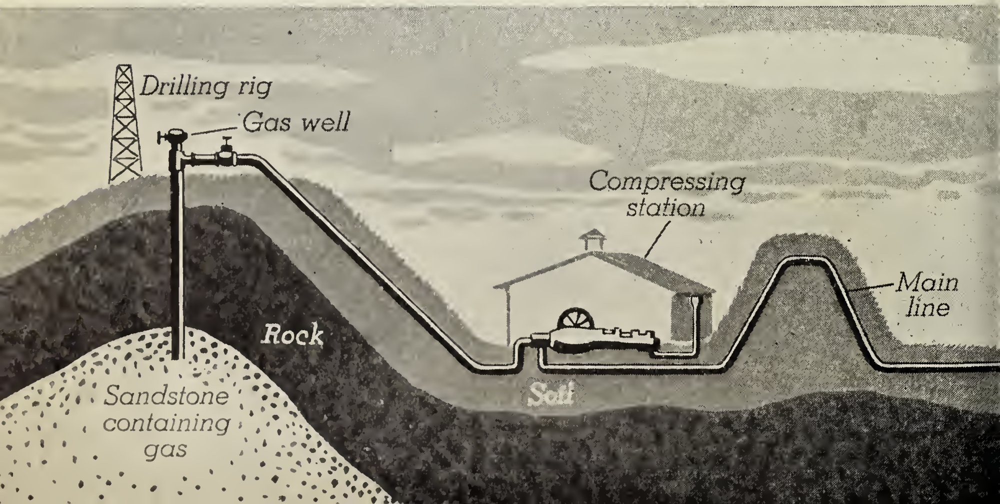
facture of coal gas. It consisted merely of a cast-iron container filled with soft coal and heated by a fire on a grate below. Coal gas formed in the container and was piped to a factory where it was burned for light.

Exercise. Place some small pieces of soft coal in a test tube and heat over a gas flame. Apply the flame to the gas escaping from the tube. Does it burn?

The use of coal gas for illumination rapidly spread throughout the civilized world. First used chiefly in street lights, it soon found its way into the home. It is still used there, though no longer to furnish light. Today coal gas is used in millions of dwellings for cooking, heating, and refrigeration.

Exercise. Make a list of all the purposes gas serves in your home and your school. If there are stores, restaurants, offices, or factories near by, make a list of all the ways you can discover that gas is used in them.

Modern Manufacture of Coal Gas. Murdoch's crude method of making coal gas has been greatly improved, so that a much better grade of gas can now be made with much greater efficiency. Soft coal is broken into very fine pieces and placed in an airtight oven, where it is baked under a very high temperature (2400° F.). The heat further breaks



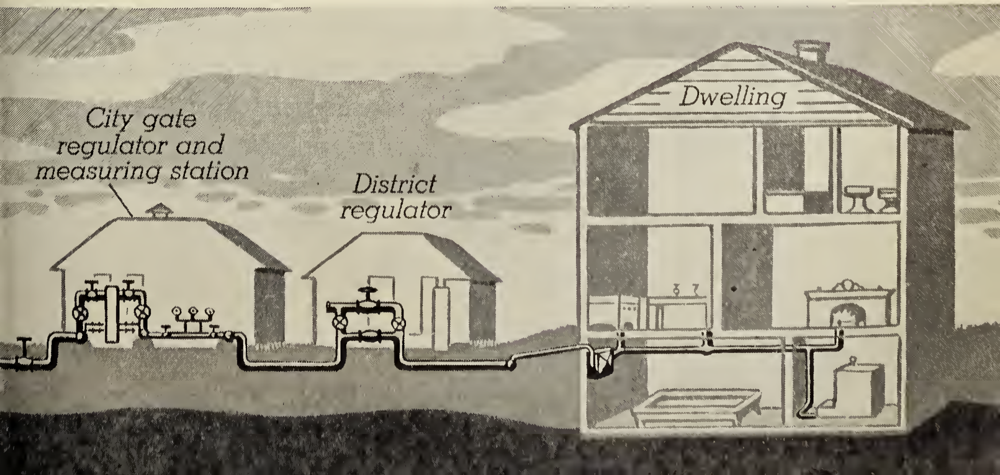
down the coal, and the gas is driven off into coolers which remove the tar it contains.

Next the gas passes through other apparatus which removes ammonia and other impurities. It is then carried to storage tanks, whence it is carried through large underground pipes (mains) to the places where it is used. The coke that remains after the gas is made goes to iron foundries and other places where it is used for heating purposes. The other by-products also find a variety of uses.

Most modern gas plants also make gas by passing steam and oil over white-hot coke or hard coal. This *water gas*, as it is called, is somewhat different in properties from gas which is manufactured from soft coal. Commercial gas is generally a mixture of the two varieties. On page 201 is a photograph of a modern gas plant.

Exercise. There is probably a gas plant in your town or city. If so, see if you can arrange to have your class shown through it. Keep notes on what you see, and write a report on your findings.

Natural Gas. In the next section of this chapter we shall learn about the origin and use of petroleum. It should be mentioned here, however, that gas almost always occurs with petroleum. In the development of oil fields throughout the world much of this natural gas has been and still is



allowed to escape into the air unused. In some cases it has been piped to towns and cities where it has proved a very satisfactory fuel. It gives off a great deal more heat than does artificial gas.

The diagram at the bottom of pages 202–203 shows the way natural gas is taken from the well to the place of use. Notice that the gas must be compressed, measured, and regulated before it goes to the user. Many towns in more than half the states in this country receive gas in this way from near-by oil and gas fields.

Exercise. In 1937 there were some ten million users of manufactured gas in the United States and some seven million users of natural gas. But nearly four times as much natural gas as artificial gas was used in that year. Can you think of any reasons for this?

THE STORY OF PETROLEUM

Ancient Uses of Petroleum. The wonder-liquid which we call petroleum ("rock oil") was known to many ancient peoples. Noah is supposed to have filled the chinks in the ark with asphalt, a product of this liquid. The ancient Egyptians used it to embalm their dead. The ancient Romans used it in their lamps. But none of these people realized that the strange mineral that oozed out of the rocks was one of the best sources of energy on earth.

Nor did the people of many later generations realize this fact. Petroleum lay for the most part untouched in its dark home underground. Though it seeped through cracks to the surface in many places, it was generally disregarded. As late as the nineteenth century, petroleum that got into the brine (salt water) wells of eastern United States was considered an impurity and a nuisance.

Discovery of the Value of Petroleum. Not until an oil made from coal (coal oil) began to be used in lamps was the true value of petroleum suspected. In 1859 a group of men conceived the idea that rock oil might compete with coal oil as a fuel for lamps. They chose a site for drilling an oil well near Titusville, Pennsylvania, and hired a man by the name of Drake to do the drilling.

Today we should laugh at Drake's clumsy oil-drilling rig. Indeed, the people of Drake's day laughed at him. But after months of labor, when the well had reached sixty-nine feet below the surface, oil began to ooze into it. Suddenly the laughter changed to wild excitement; people realized what petroleum might come to mean. Wells were drilled everywhere, and rock oil took its place among the most eagerly sought materials in the world.

As a source of power, as the chart on page 196 shows, petroleum has gone ahead of water and anthracite. Only bituminous coal is ahead of it as an energy-producing mineral, and each year this lead is being cut down a little. Though most petroleum is used as gasoline for automobiles and fuel oil for engines, furnaces, and boilers, there are many other useful forms of this mineral. There are, to mention only a few, the oils used for lubricating machinery, the asphalt used for building roads, the paraffin used for canning, and the naphtha used for cleaning. Indeed, more

With this crude drilling rig, Colonel E. L. Drake (in tall hat) brought in the world's first oil well and founded a mighty industry

Brown Brothers

than three hundred products of petroleum have already been put into use, and many more will doubtless be developed in the future.

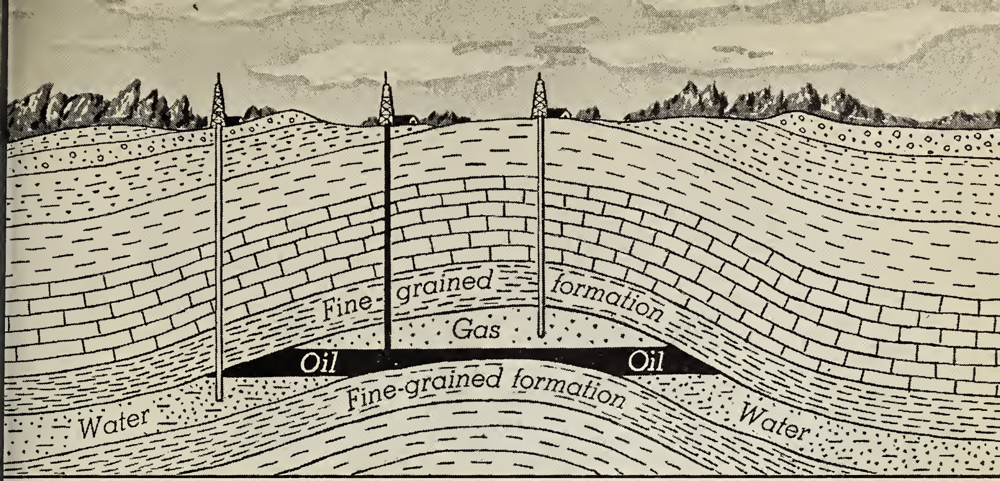
Exercise. Make a list of as many different petroleum products as you can think of. See what member of the class can make the longest list.

Origin of Petroleum. Petroleum is a complex compound of carbon and hydrogen. Though it differs in chemical and physical properties from place to place, most authorities believe that all of it is the result of decaying plants or animals which lived in the shallow seas of past ages. It is thought that under the activity of bacteria the flesh of these creatures turned into petroleum which was later buried in the mud of the sea bottom.

With time the imprisoned drops of oil are thought to have been squeezed together as more and more sediment settled upon them. Later the sediments hardened into rock and were uplifted to form land. The petroleum moved through the coarser-grained formations, pushed by the underground water that was also slowly seeping through the rocks. It continued to move until such a "structure" as is shown on the opposite page stopped it.

In such structures as this the most valuable oil pools of the world occur, sometimes thousands of feet below the surface of the earth. The geologist, however, can locate the places where petroleum is likely to be found by carefully studying the rock formations that appear at the surface. The producing oil fields of the United States are shown in the map on page 208.

How Petroleum Is Taken from the Earth. When the spot for drilling an oil well has been chosen, a derrick is built. Most

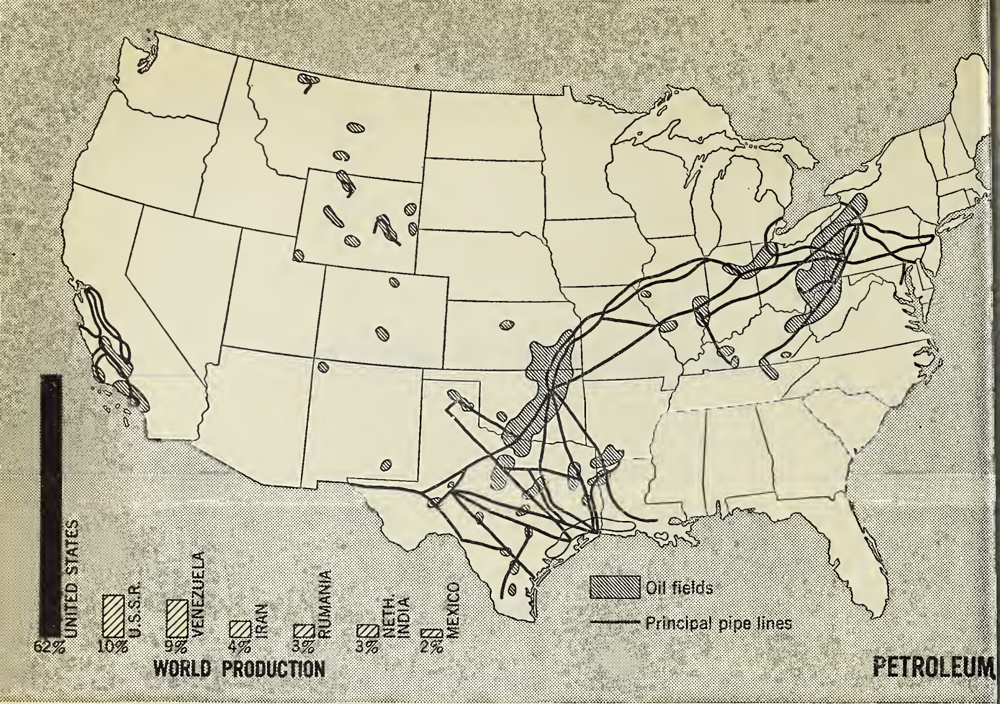


ıe gas and oil shown in this diagram were pushed by water through the pores of a arse-grained layer of rock which was sealed above and below by fine-grained formans. Entering the arching "structure," the light gas and oil were trapped. Notice w the position of a well on the "structure" determines whether it strikes water, oil, or gas

modern oil derricks are made of steel, and the drilling is done by the so-called rotary method. By this method a pipe (drill pipe) with a cutting instrument (bit) at its lower end is hoisted into a vertical position by pulleys at the top of the derrick. The drill pipe and bit are then inserted into a round platform (rotary table) which is turned by an engine. This table twists the pipe and bit into the earth much as a screwdriver twists an iron screw into wood (see photograph on page 211).

As the drill pipe and bit are forced into the earth, more lengths of pipe are attached to the pipe already in the ground. As the bit eats its way downward, pipes (casing pipes) which are larger than the drill pipes are fitted into the drill hole. These make a protecting shell around the drill pipes and also prevent the sides of the hole from caving.

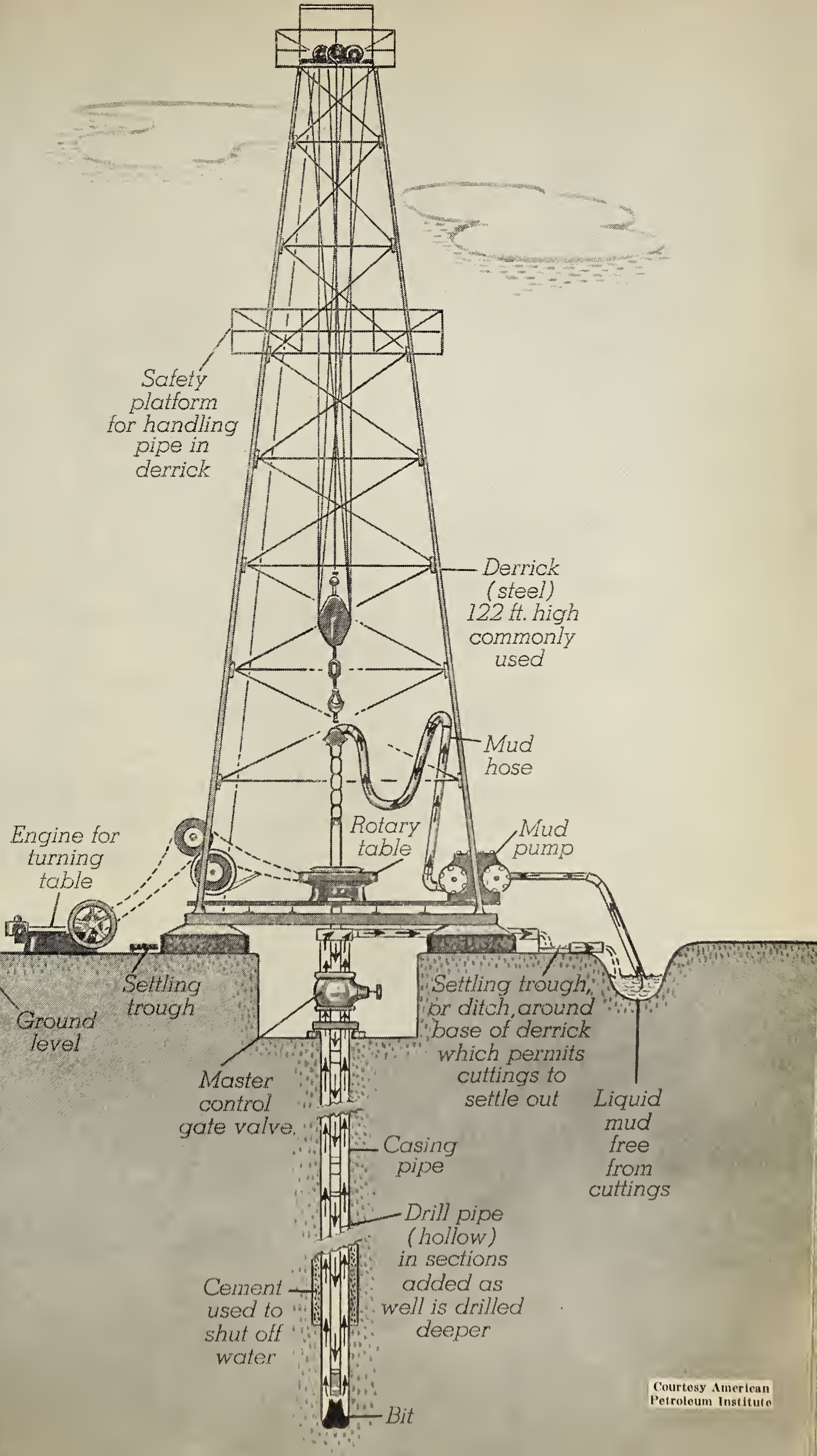
The diagram on page 209 shows in detail how a rotary oil rig works. Notice that a steady stream of mud is kept circulating down through the drill pipe and up through the



This map tells the story of the location and production of petroleum in the United States. The black lines represent pipe li

space between the drill pipe and the casing pipe. This mud removes from the well the rock fragments (cuttings) that the bit grinds out. If the well is a success, there will come a day when the mud will begin to smell of petroleum and take on a darker color. Then as the bit bites farther into the oil-bearing formation, the oil may rise through the pipe under pressure of the gas and water with which it is associated in the rocks.

In the old days the oil sometimes rushed upward with enough pressure to blow out the pipes and ruin the well. Under modern drilling methods such a catastrophe almost never happens. By a system of valves the flow is controlled from the start. Some of the natural gas which comes up with the oil is caught and forced down into the well again. In this way enough pressure is maintained in the well to



Safety platform for handling pipe in derrick
Derrick (steel) 122 ft. high commonly used
Mud hose
Engine for turning table
Rotary table
Mud pump
Settling trough
Ground level
Settling trough, or ditch, around base of derrick which permits cuttings to settle out
Master control gate valve
Liquid mud free from cuttings
Casing pipe
Drill pipe (hollow) in sections added as well is drilled deeper
Cement used to shut off water
Bit

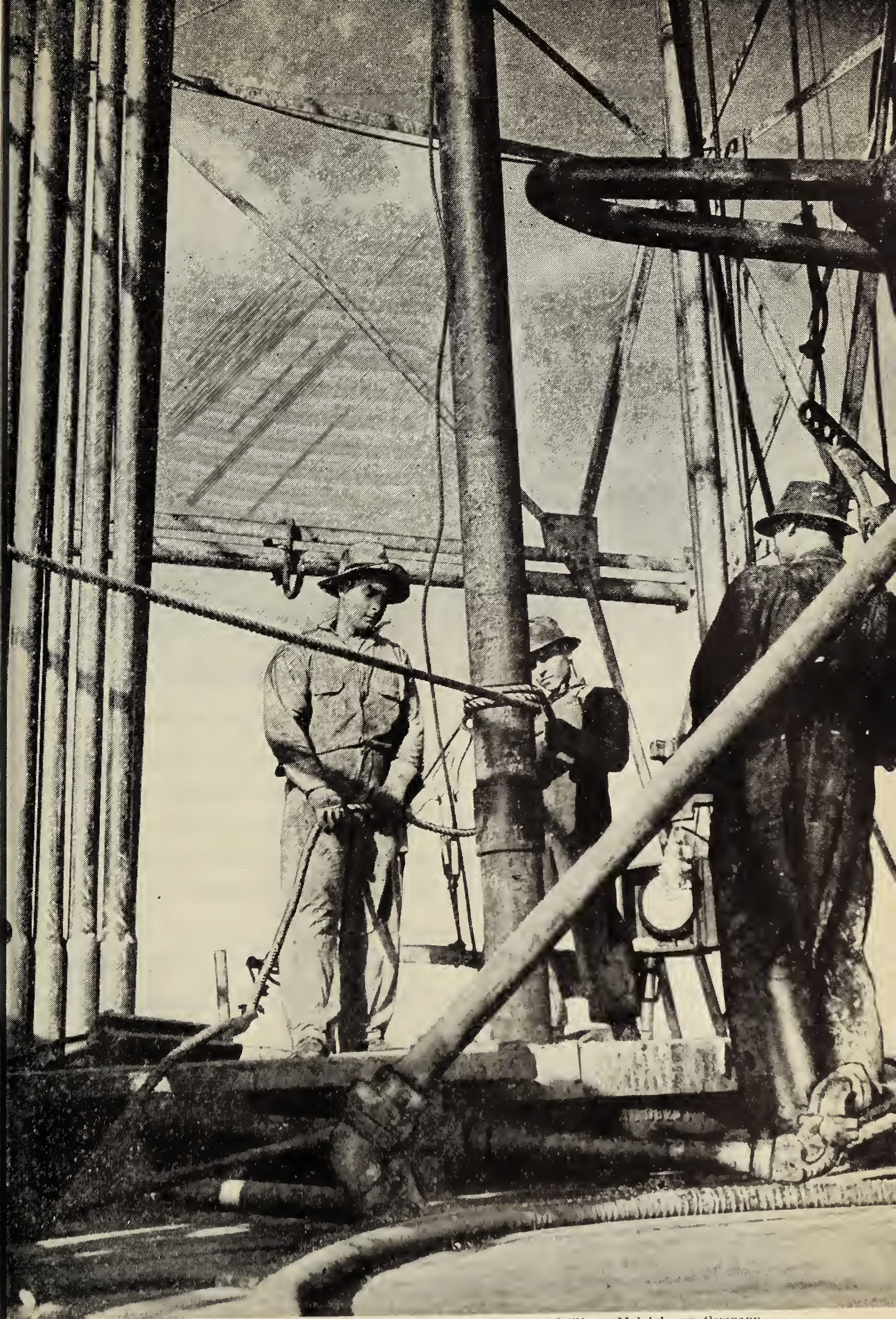
Courtesy American Petroleum Institute

keep the oil flowing upwards until all of it has risen to the surface.

How Petroleum Is Refined. Petroleum is sometimes called "black gold." Though its properties vary widely from place to place, most petroleum is dark enough and valuable enough to merit the nickname. The strong-smelling liquid that comes out of an oil well is known as *crude oil.* This crude oil is taken to refineries chiefly through an underground network of pipes, which many people do not realize exists. The map on page 208 shows the chief pipe-line systems in the United States. Though some crude oil is carried by boats (oil tankers) and by railroads, most of it reaches the refineries through pipe lines. Over one hundred thousand miles of hidden pipe carry more than a billion barrels of petroleum every year.

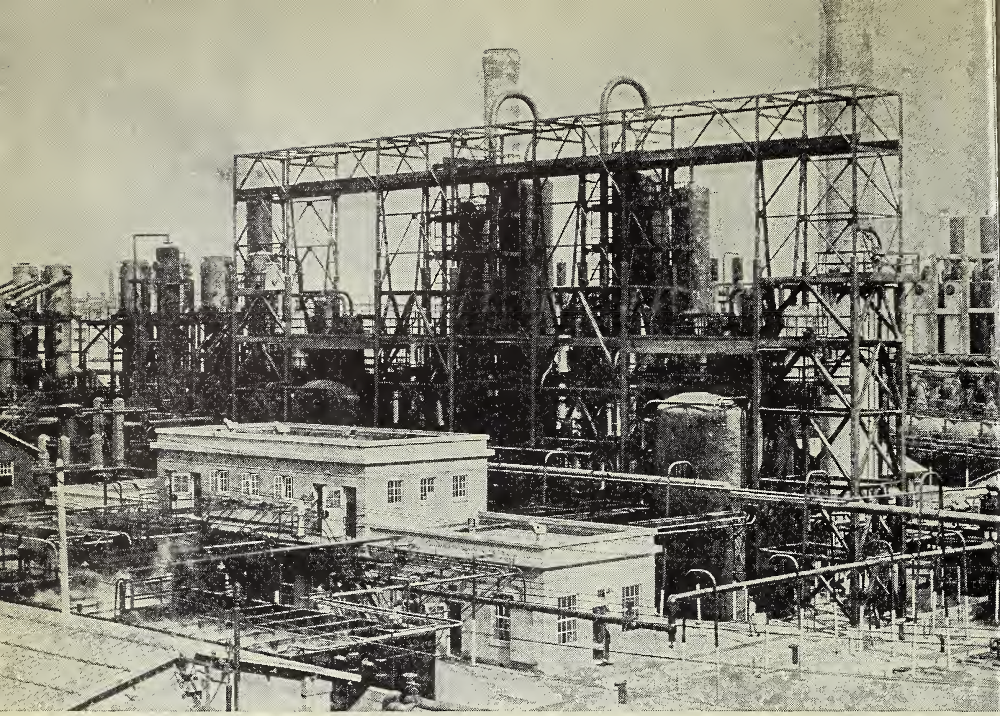
Oil refineries are among the most complicated factories in the world. As the photograph on page 212 shows, such a plant consists of a wilderness of pipes, towers, tanks, and other apparatus. There the crude oil is heated. Different kinds of vapors are driven off at different temperatures, and these are collected in separate condensers, where they are cooled and changed back to liquid form.

Raw *gasoline*, raw *kerosene*, *gas oil*, and *lubricating oils* are the four chief products of an oil refinery, and they are given off in that order as products of the heating of crude oil. The gasoline, kerosene, and lubricating oils are then purified by complicated chemical processes. The gas oil is "cracked" by intense pressure and heat, and more gasoline is extracted. Some of the best modern gasoline comes from this cracking of gas oil, gasoline which was lost in the early days of oil refining. After the gas oil is cracked and the gasoline extracted from it, *fuel oil* remains.



Robert Yarnall Richie and Climax Molybdenum Company

These men are working on a rotary drill. Notice the lengths of pipe that will be fitted into the drill hole as the bit grinds deeper and deeper into the earth



The modern oil refinery is an extremely complicated factory

Exercise. There are more than six hundred oil refineries in this country. If one of these is in the vicinity of your home, see if you can arrange to have your class visit it, take notes on what you see, and when you return home write a report on "How Petroleum Is Refined."

The Strength of Union. We have now come to the end of our survey of the mineral treasures of the earth. We have seen that modern civilization is built on a variety of minerals without which it could not exist. Indeed, one of the gravest problems of our day is just how to divide this wealth among the peoples of the world to insure peace and good will among men.

Europe, torn by war throughout its history, is a fine example of how mineral wealth should *not* be divided. Like a house divided against itself, a continent so divided cannot stand. As long as Europe is separated into many nations, some rich and others poor in the treasures of earth, the seeds of war will grow. *All nations need all types of mineral materials to be prosperous and peaceful*, and there is a growing belief that the only way to get these blessings is through some kind of union.

At this time of mighty conflicts among men, the rest of the world might learn a lesson from the United States. Arizona with most of the copper of North America and California with most of the oil do not glare at one another across a fortified boundary. Pennsylvania with most of the anthracite is not in danger of invasion from New York, which has none of it. Through union, all the states of the United States exchange their wealth in peace, and all are prosperous to a degree that makes them the envy of the rest of the civilized world.

By combining instead of dividing its mineral resources the United States has become the world's leading producer of the raw minerals on which modern life is founded. It produces, for example, 29 per cent of all the iron in the world, 32 per cent of all the copper, 34 per cent of all the coal, and 62 per cent of all the oil. It is much the richest and most peaceful nation in the world and will remain so until other peoples have learned that co-operation is more profitable than conflict.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Though coal, gas, and petroleum are important sources of energy in the modern world, they play second fiddle to running water.

2. Next to petroleum, coal is the most widely used fuel on earth.

3. Anthracite is the most abundant and most widely used of all the varieties of coal.

4. Most coal is mined with electric shovels at the surface of the earth.

5. Coke is a form of low-grade coal which as yet has been little used.

6. Gas made from coal is widely used today, chiefly to provide light.

7. Lignite coal is the chief source of coal gas.

8. Natural gas is a valuable by-product of coal-mining.

9. Both coal and petroleum have been important sources of energy since the days of the ancient Egyptians.

10. Most petroleum is made into fuel oil for engines, furnaces, and boilers.

11. The saying "Oil is where you find it" is based on the fact that oil may be discovered in the rocks practically anywhere.

12. Crude oil is just another name for the fuel oil that is used in engines, furnaces, and boilers.

13. All the gasoline in petroleum is given off as a vapor when crude oil is heated.

14. The process of extracting kerosene from petroleum is known as cracking.

Questions for Discussion

1. Do you think there is any limit to the supply of fuels discussed in this chapter? If so, what do you suppose we shall do when the supply is exhausted?

2. If all fuels were equally expensive to use in the furnace or boiler of your home, which one would you prefer? Why?

3. Do you believe that the distribution of coal and petroleum has any bearing on the troubles of the world today? If so, what is it?

Things to Do

1. Make a careful study of all the activities in your home which require the use of fuels. Write a report describing each of these activities and the kind of fuels used. Estimate the cost of each fuel so used.

2. The world is full of new and interesting uses for coal, gas, and petroleum. Make a Fuel Scrapbook of newspaper and magazine clippings concerning these uses.

3. On an outline map of the world show by different shading the chief deposits of coal and petroleum. You can get the necessary information from books on geography, mineral resources, or from an encyclopedia. Can you see any relationship between fuel resources and the political power of the various nations of the modern world?

4. The Encyclopædia Britannica, 14th Edition, has accurate detailed descriptions with many diagrams on the modern manufacture of gas, and also on the recovery and use of coal and oil. For those who care to study these matters more deeply than we have been able to do in this chapter, reports may be made on the basis of the Britannica articles.

5. Read *All about Treasures of the Earth*, by Frederick A. Talbot. It contains fascinating chapters on coal and oil, as well as on many of the other minerals studied in this unit.

UNIT THREE

PUTTING ENERGY TO WORK

◆

In the days of our far-distant ancestors, the living resources of earth spread over land and sea uncultivated and untamed.

The mineral treasures lay idle in the ground.

Men could use neither the creature nor the mineral wealth of the world until they had learned to use another and very different kind of wealth.

Not until then could they reap the harvests that they enjoy today.

◆

Not until men had learned to control this third great natural treasure could they invent the machinery that does so much work in the modern world.

Not until then could they effectively heat and light their homes.

Not until then could they communicate with one another over vast distances, or travel to far places with comfort, safety, and speed.

Not until then could they develop civilization.

◆

But what is this wealth that has done so much for men, and how have men used it so widely to improve the conditions of their lives?

It is these questions that this unit will attempt to answer.

◆

CHAPTER EIGHT

How Do We Make Machinery Work?

THE NATURE OF WORK

What Makes the World Go Round. In the first two units of this book we studied the natural resources which men use to make their lives more comfortable and safe. But what makes it possible for men to use these resources as they do? What is it that drives men on in their endless struggle to improve their condition under the sun? What is there in the materials which men use that helps them in this struggle? These are mighty questions for which there are many answers, depending on the point of view of the person who does the answering. The scientist would answer them all with a single word: energy.

Energy is that mysterious quality of man and the world which keeps things forever on the move. We see the results of energy when rain beats down from the sky and then flows as a river to the sea. We see the results of energy when we watch a seedling grow up in the garden or a cow munch hay in the barn. We ourselves use energy when we push or pull or lift an object, and when we move from one place to another. *We may therefore define energy as that which makes things move their position or change their form.*

What Force Is. Though nobody can see energy, anybody can see what energy does. *Anybody can see that energy operates by exerting a push or a pull, which we call a force.*

Anywhere we look we may see forces at work. Water flowing in a river exerts force as it moves the rocks in its bed. A strong wind may strike with enough force to break trees or to rip the chimneys off buildings. With forces developed in your muscles, you walk, run, kick footballs, bat baseballs, and do many other things.

In doing the work of the modern world we must raise and distribute food. We must make clothing, machinery, and many other things. We must build dams, bridges, and buildings. For all this work forces must be applied. In the earlier periods of human history work was done chiefly by the muscles of men and beasts. Slaves drove ancient vessels by means of oars. Horses and camels pulled heavy loads over the land. With the nineteenth and twentieth centuries, however, great changes came about. Men learned how to make many different kinds of forces do the work which was once done chiefly by muscle.

What Work Is. Before we can understand how men use forces to perform work we must understand what we mean by work. We say that we do "a day's work" or that we "work on a problem." We speak of the "work of the world" or the "work that a factory is doing." These are unscientific uses of the word "work" which have no exact meaning. When an engineer speaks of work he has a very definite meaning in mind, a meaning which is probably very different from any you have ever attached to the word.

If, for example, you push against a piano that will not budge, you probably think of yourself as working very hard. In the scientific sense of the word "work," however, you are not working at all. You accomplish work only if you move the piano. Scientifically speaking, *work is done when a definite force moves a definite weight through a* *definite distance.* Force and distance may be accurately measured; so work by this definition may also be accurately measured.

Suppose you have on your desk a one-pound sack of sugar. If you raise this sack of sugar through a distance of one foot, one *foot-pound* of work may be said to be accomplished. Similarly, if you raise it two feet, two *foot-pounds* of work are done. If you raise two pounds through two feet, four foot-pounds of work are done, and so on. The foot-pound is thus a convenient unit for measuring work.

The Force of Gravity. It is easy to see that when we do work by the above definition we must overcome some sort of resistance. What are the forces that we must overcome when we do work? There is first of all the *force of gravity,* which exerts a pull between any two objects no matter what their size nor where they are. Nobody knows exactly what this force is, but we do know that it operates throughout the entire universe. It operates between the stars in space and also between the pencils on your desk.

We know that the heavier the object the greater is its power to pull at some other object. The attraction of the pencils on your desk for one another is very slight, but the attraction of stars for one another is tremendous. The attraction between the earth and objects on its surface, though shared by both, seems to work only in the direction

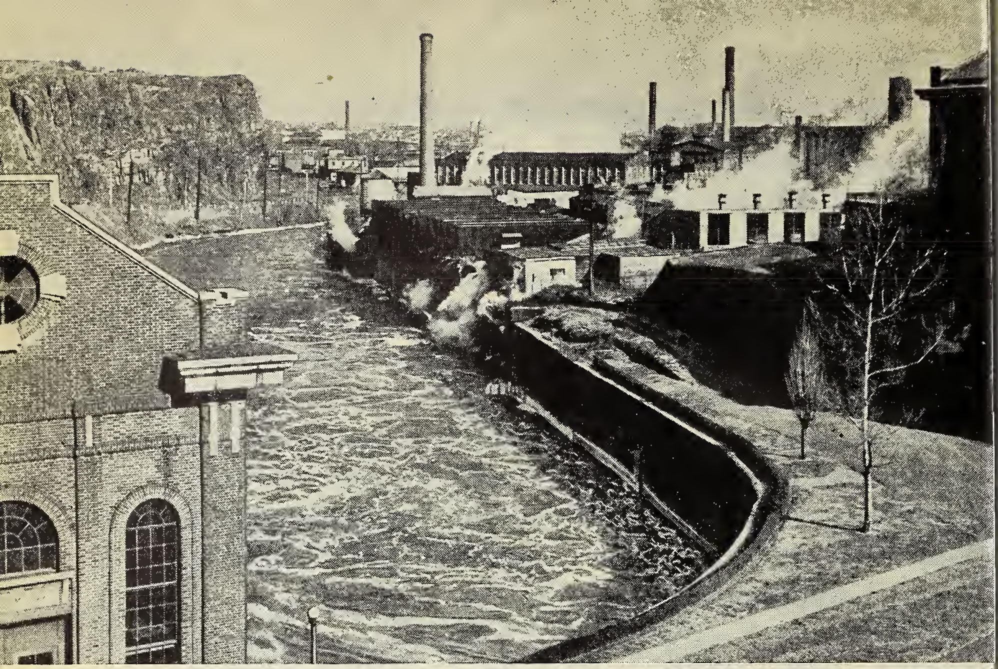
This girl is measuring work in terms of foot-pounds

of the earth because the earth is so much larger than anything on its surface. When you drop a pencil from your desk, for example, it drops downward toward the earth because the attraction of the large earth for the small pencil is much stronger than the attraction of the pencil for the earth.

The pull exerted between the earth and objects on its surface gives objects their weight. When we say that a sack of sugar weighs one pound, we are really giving a measure of the force of gravity. When we lift the sack of sugar one foot and say that we thereby do one foot-pound of work, we are really giving a measure of the force with which we have overcome the force of gravity.

Exercise. How to measure the force of gravity: Make a simple spring scales by fastening one end of a coiled spring to a solid support in such a way that the coil will hang in a vertical position. Measure the length of the unstretched spring, then fasten a small stone or other light object to the lower end of the spring and measure the length of the spring again. Do this for various objects, measuring in inches and fractions of an inch how much the spring stretches in each case. Do you see that each measurement is the measurement of the attraction between the earth and the object at the end of the spring?

The force of gravity contributes certain conveniences toward living on the spinning ball we call the earth. Without gravity we should be flipped off into space if we ever let go of some solidly anchored object. Gravity also gives water the energy of motion which enables it to run downhill. This running water is made to turn the wheels of factories and power plants, which in turn do a great deal of work.



Gendreau

Water moved by the force of gravity turns the wheels of power plants and factor

The force of gravity, on the other hand, offers a great deal of resistance to motion. Our lives are made up to a considerable extent of lifting and moving. We must lift ourselves when we get out of bed and when we walk or run over the ground. We must lift the lumber that goes into our houses and the steel that goes into our skyscrapers. Because gravity pulls on everything, it offers resistance to many activities. Many of the machines which we have designed to help us work must fight this mighty force, as we shall see as we go on with this unit.

Inertia. Objects do not start moving by themselves. Some push or pull, which we call force, is needed to get them going. A man, for example, can move an automobile over the cement floor of a garage without help from the engine, but he must push very hard to get it started. This resistance of the automobile to motion is called inertia.

Exercise. Place a piece of paper on top of your desk and some books on top of the paper. Take hold of one end of the paper and jerk it out quickly from under the books. What happens to the books? Why?

Once the automobile is set in motion, however, the man does not have to push so hard to keep it rolling. Indeed, if he wants to stop its movement quickly he must pull back. The automobile offers the same sort of resistance to being stopped as it did to being started. In other words, *objects at rest tend to remain at rest; moving objects tend to go on moving.*

Exercise. Push a marble over the top of a table fairly rapidly with a pencil, then suddenly stop the motion of the pencil. What happens to the marble? Why?

Inertia, like gravity, both helps and hinders our activities. It is a help to have our automobile "stay put" when we park it, and not go wandering round the town by itself. It is a saving of fuel to have it go along easily once it is started. It hinders us, however, to have our car refuse to move when it runs out of gasoline. It is often tragic when a car refuses to stop when it strikes another car.

In building machines to deal with the energy of motion, man has been both helped and hindered by the force of inertia. In what ways we shall see as we continue with the study of this unit.

The resistance of objects to motion is shown by this high-speed photograph of a football at the exact moment of a kickoff

Edgerton, Germeshausen, and Grier, M. I. T.

Friction. Once an object starts moving there are many forces that might make it stop. The most important of these is friction. *Friction is the resistance, or drag, which is brought about when two surfaces are rubbed together.* You produce friction, for example, when you rub sandpaper on wood or a rubber eraser on paper. You have probably noticed from your own observations that *the smoother the surface the less friction there will be between it and an object moving over it.*

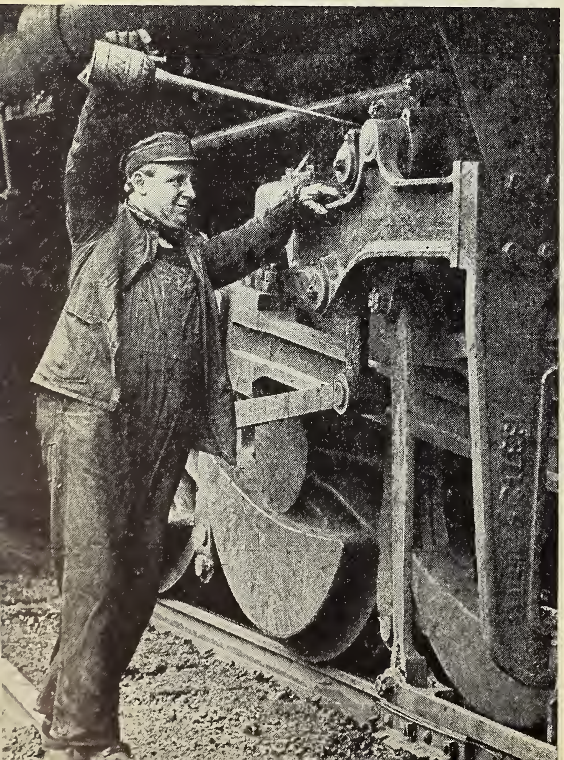
Friction, like gravity and inertia, is both helpful and harmful to man. When your car skids on an icy pavement, it is because the smooth ice has reduced friction between the tires and the road. The proper use of friction is necessary in driving a car, no matter what the weather. You must have tires which are not smooth, so that the car may be kept on the road. You must also have brakes which will create enough friction to stop the wheels.

Friction in the engine of the car, on the other hand, hinders necessary movement. That is why oil must be kept flowing over all the moving surfaces. Friction is the enemy of all moving machinery, and oil tends to reduce it by making smooth the surfaces on which movement takes place. Oiling the moving parts of machines is known as *lubrication.*

Lubrication is an important but not the only means

Oiling the moving parts of machinery is one of the chief ways of reducing friction

Galloway



These pupils are studying the effect of ball bearings on friction

of reducing friction in machinery. Have you ever looked at the works of a fine watch? The moving wheels turn like tops on tiny pointed spindles. The surfaces against which the spindles turn are tiny jewels, which not only reduce friction by being smooth but also reduce wear by being extremely hard.

Where the movement is a sliding rather than a turning one, rollers may be used to reduce friction between moving surfaces. If you own a good pair of roller skates, you know that tiny steel balls (ball bearings) separate the turning wheels from the stationary axles. By this means the smoothest and smallest possible surfaces of support are provided for the spinning wheels.

Exercise. Push a heavy book or box over the top of a table. Does friction make it drag? Now roll the book or box on four marbles. Does it move more easily? Why?

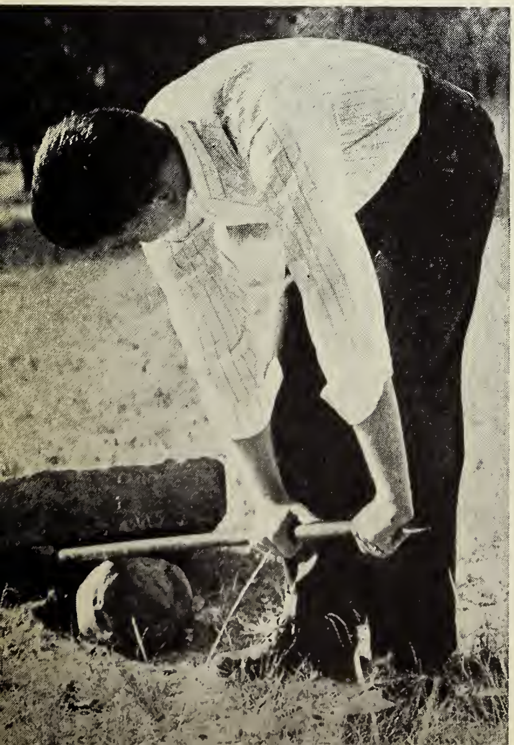
Machines and Work. Perhaps the most conspicuous feature of modern civilization is the use of machines to do work. These machines are designed to make forces perform work by overcoming resistance which occurs chiefly in the form of gravity, inertia, and friction. Let us study a few of the simpler machines and see exactly what they do.

THE LEVER, SIMPLEST OF ALL MACHINES

The Six Fundamental Machines. Everywhere we look we see machinery of one sort or another. Through this machinery man is making the forces of nature perform a vast amount of useful work. In thousands of factories, power plants, mines, and over the highways, seaways, and airways of the world, machines are busily at work. But what exactly is a machine?

We ordinarily think of a machine as something very complicated, such as a locomotive or an automobile. The world, however, is full of much simpler devices which are also machines. Shovels, tack hammers, pliers, baseball bats, oars, wheelbarrows, screws, screwdrivers, jacks, pulleys, and a host of other common implements are all machines. Indeed,

This boy is working with a lever of the first class. Can you locate the fulcrum, the force, and the resistance?



all machinery, no matter how complicated, can be reduced to six fundamental and simple machines. These six machines play countless roles in the modern world, and indeed are the very basis of the Machine Age. They are known as the lever, the pulley, the wheel and axle, the inclined plane, the wedge, and the screw.

The Lever. On the opposite page you see a boy solving a problem with the help of a long iron bar (crowbar). He wants to move the large rock which is much too heavy to be pushed or lifted without some help. Accordingly, the boy has pushed one end of the crowbar under the edge of the large rock. He has placed a small rock under the crowbar close to the large rock to act as a support, or *fulcrum*, for the crowbar. By pushing on the free end of the crowbar, the large rock is easily lifted.

The crowbar which the boy used to do this simple piece of work is an example of a lever. *With its help the boy was able to change a small force exerted downward at one end of the lever into a powerful force exerted upward at the other end of the lever.* Suppose that the large rock weighs 300 pounds and that the small rock, or fulcrum, is set just 6 inches from the large rock. Suppose that it is just 5 feet from the fulcrum to the end of the bar where the boy applies the force. You could show by measurement that a force of about 30 pounds applied at the end of the lever will be sufficient to raise the load of 300 pounds.

Notice the advantage that is gained through the use of the lever. In this case a force of 30 pounds overcomes a resistance, or opposing force, of 300 pounds. *The relation, or ratio, of resistance to effort is called mechanical advantage.* In this case the mechanical advantage is 10 ($\frac{300}{30} = 10$).

How much mechanical advantage may be gained through the use of a lever of this type? If the short lever arm (the distance between the fulcrum and the resistance) were made shorter, or the long lever arm (the distance between the fulcrum and the force) longer, the mechanical advantage would be greater. Archimedes, a scientist of ancient Greece, said that if he could have a lever that was long and strong enough, and a fulcrum to support it, he could move the earth.

How the Lever Helps Us Do Work. But how much work is done at each end of the lever? How does the work done in pushing the end of the lever down compare with the work done in raising the load? In other words, how does the work put into the machine compare with the work that comes out of it?

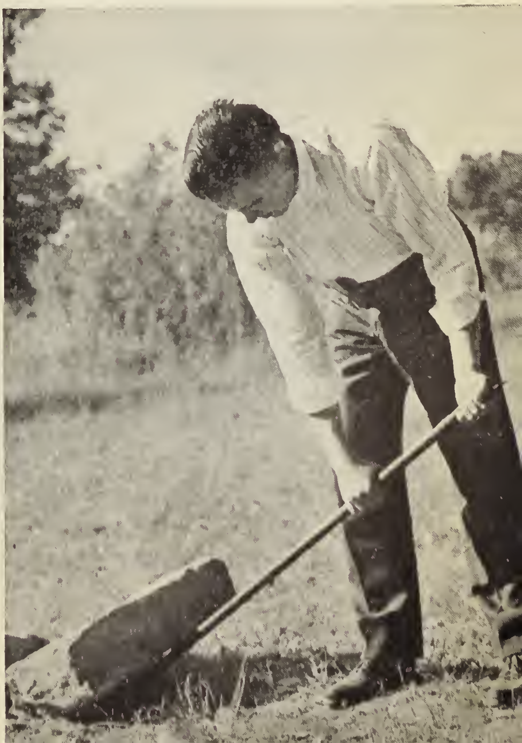
Let us say that the boy shown on page 228 raises the large rock 2 inches. Two inches is 1/6 foot. The work done in raising 300 pounds 1/6 foot is 50 foot-pounds ($300 \times 1/6 = 50$). The force of 30 pounds which the boy applies at the free end of the lever moves through a much greater distance than 1/6 foot as the large rock is raised. Measurement would show that this force moves through 20 inches, or 1 2/3 feet, while the load end of the lever is raised 1/6 foot. Therefore, the work done at the free end of the lever is also 50 foot-pounds ($30 \times 1\ 2/3 = 50$). *In other words, the work done where the force is applied at the end of the lever (50 foot-pounds) is just equal to the work done in raising the load (50 foot-pounds).*

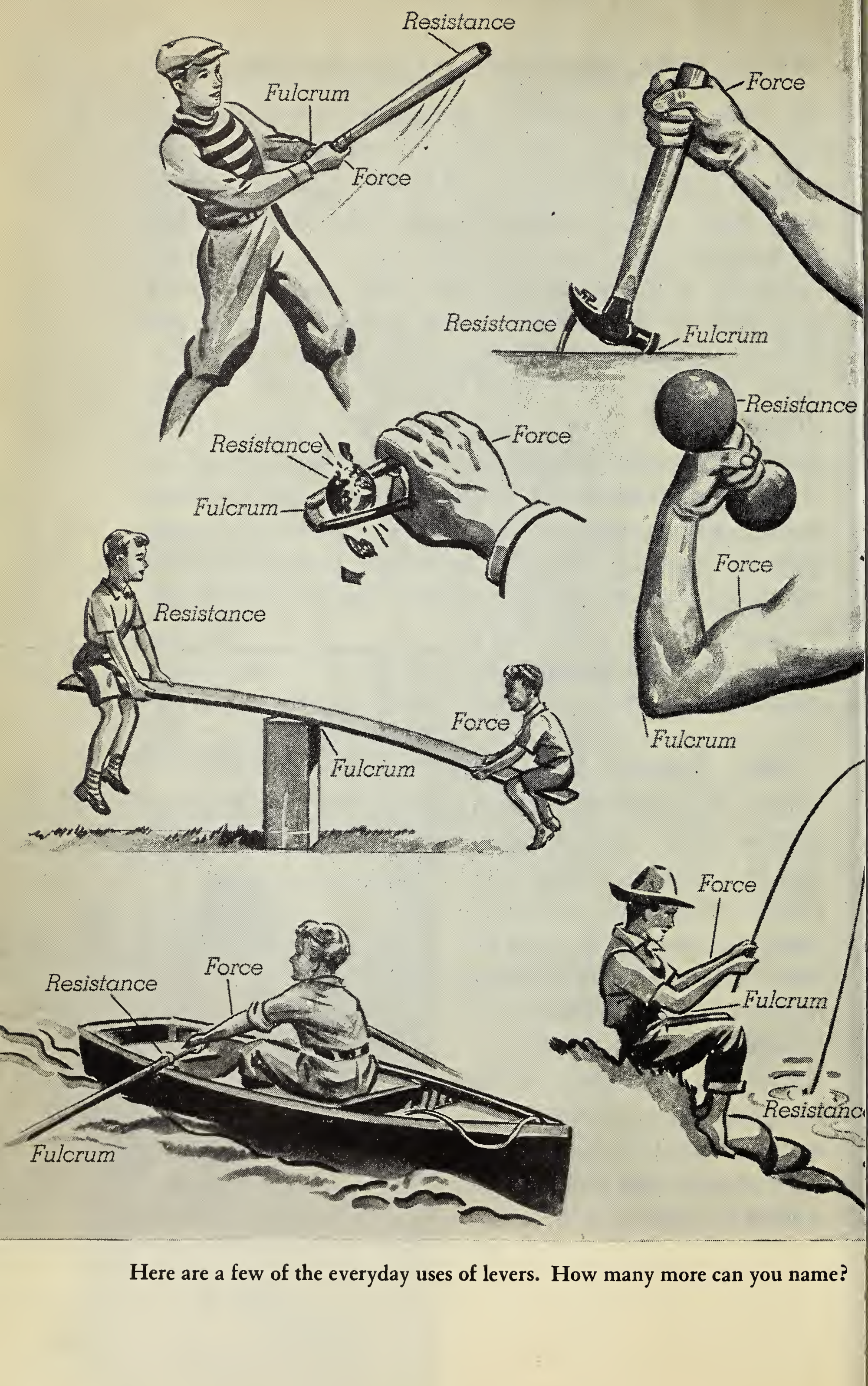
This little problem in arithmetic illustrates an important principle which applies to all machines. Though at first thought it might seem that less work is put into a machine than is got out of it, this is never so. In simple levers where very little effort is needed to overcome friction, the best that can be done is to get about as much work out of the machine as is put into it. In most machines, however, friction consumes effort, with the result that less work is got out than is put in.

"If this is true," you may well ask, "then why do we use machines? If we must put more work into most machines than we get out of them, what good are they?" The answer is simple enough if we think of what the boy was able to do with the help of the lever. He could not have moved the large rock at all unless he had used some kind of machine which could change a small force working through a longer distance into large force working through a shorter distance. Since the business of all machines is to change small forces into large forces in this manner, we can accomplish tasks with their help which would otherwise be impossible.

Some Different Types of Levers. The lever performs a greater variety of tasks than any of the other simple machines, and the illustrations on page 232 show several of its most common uses. Notice that in some levers the fulcrum is between the force and the resistance, as in the case of the boy and the crowbar described above. This is the commonest type of lever and is known as a *lever of the first class.*

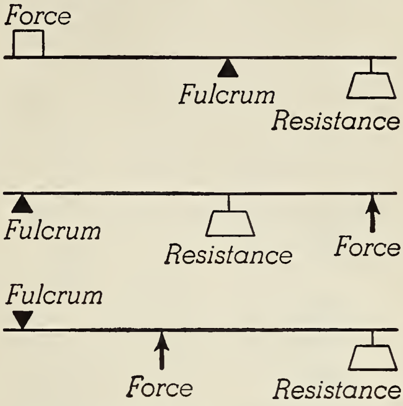
This boy is working with a lever of the second class. Can you locate the fulcrum, the force, and the resistance?





Here are a few of the everyday uses of levers. How many more can you name?

Exercise. List all the levers of the first class which are pictured on the opposite page. List as many more simple levers of the first class as you can think of.



This diagram illustrates the operation of first-class (top), second-class (middle), and third-class (bottom), levers

If the boy pictured on page 228 had placed the crowbar under the large rock and pushed up instead of down, he would have used the bar as a *lever of the second class.* The illustration on page 231 shows him using the lever in this fashion. In this case the end of the bar under the rock is the fulcrum, and the resistance is between the fulcrum and the force.

Exercise. If the boy had to move or lift the rock a long distance, would a lever of the first class or a lever of the second class be better? Why?

There is finally a *lever of the third class,* where the force is between the fulcrum and the resistance. The boy shoveling coal in the illustration on page 234 is using such a lever. In this case the boy's hand on the handle acts as the fulcrum and his other hand delivers the force. The diagram above will clearly show the differences between the three types of levers.

Exercise. Are there any levers of the third class shown on the opposite page? How many simple levers of the third class can you think of? Do you think that levers of this class are as efficient as those of the other classes? Why?

Though the mechanical advantage of these different types of levers varies considerably, the principle of work is the same in all. This principle may be expressed briefly as follows: *the product of the force times the distance through which it moves is the same as the product of the resistance times the distance through which it moves.* If this principle is still a little hazy in your mind, review the arithmetic problem on page 230 which illustrates it.

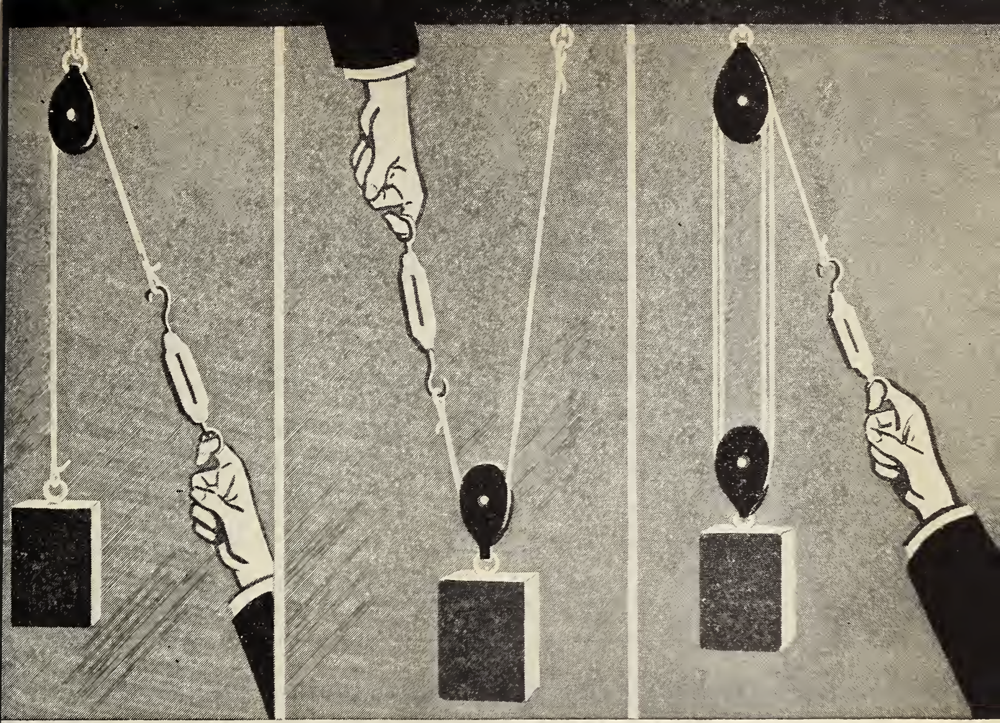
Exercise. An automobile jack is one of the commonest examples of levers. Get a simple jack and see if you can determine what type of lever it is, and about what its mechanical advantage is.

SOME OTHER SIMPLE MACHINES

The Pulley. Very closely related to the lever is another simple machine which is known as a pulley. A pulley is a combination of a cord, rope, or cable and a small grooved wheel. There are three different kinds of pulleys, and the illustrations on the opposite page show how they are rigged to do work.

Fixed Pulleys. Let us look first at the picture on the opposite page which illustrates what is known as a single fixed pulley. By pulling *downwards* on one end of the rope, a weight at the other end is lifted *upwards.* The only advantage of such a pulley is that it changes the direction of applying a

This boy is working with a lever of the third class. Can you locate the fulcrum, the force, and the resistance?



e are shown the three types of pulleys: the fixed pulley (left), the movable pulley (middle), and the block and tackle (right)

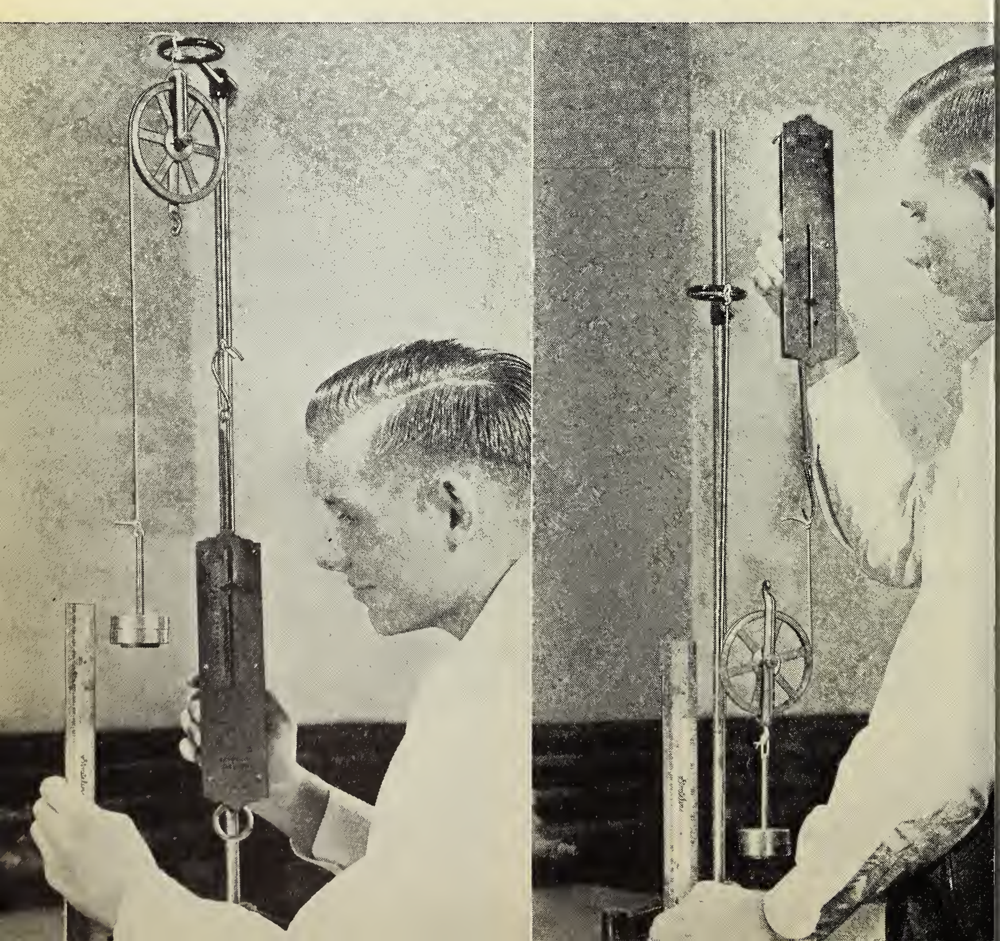
force. Because of friction between the rope and the wheel, the force at the one end must be a little greater than the weight (resistance) at the other end.

Perhaps you have seen a farmer hoisting a load of hay into a barn by means of a single fixed pulley. If you look closely at such a pulley, you will see that it is really a lever of the first class. The pulley is the fulcrum, and it occupies a position between the force and the resistance. It is a lever, however, with no mechanical advantage because the force and resistance are equal.

Exercise. Get a small pulley, a stout cord, a one-pound weight, and a simple spring scales, as shown on page 236. Attach the pulley to some solid support overhead and rig it as shown in the diagram. Then, without jerking, pull the end with the scales downwards one foot and observe how far upwards the weight moves. Observe on the scales how much force was used to lift the weight and then estimate the mechanical advantage of the machine.

Movable Pulleys. The second type of pulley, illustrated on page 235, is known as a single movable pulley. Notice that this kind of pulley is really a lever of the second class, because the fulcrum is the end of the rope which is attached to the support, and the resistance lies between this and the force. Movable pulleys are more efficient than fixed pulleys

This boy is determining the mechanical advantage of a fixed pulley (left) and a movable pulley (rig



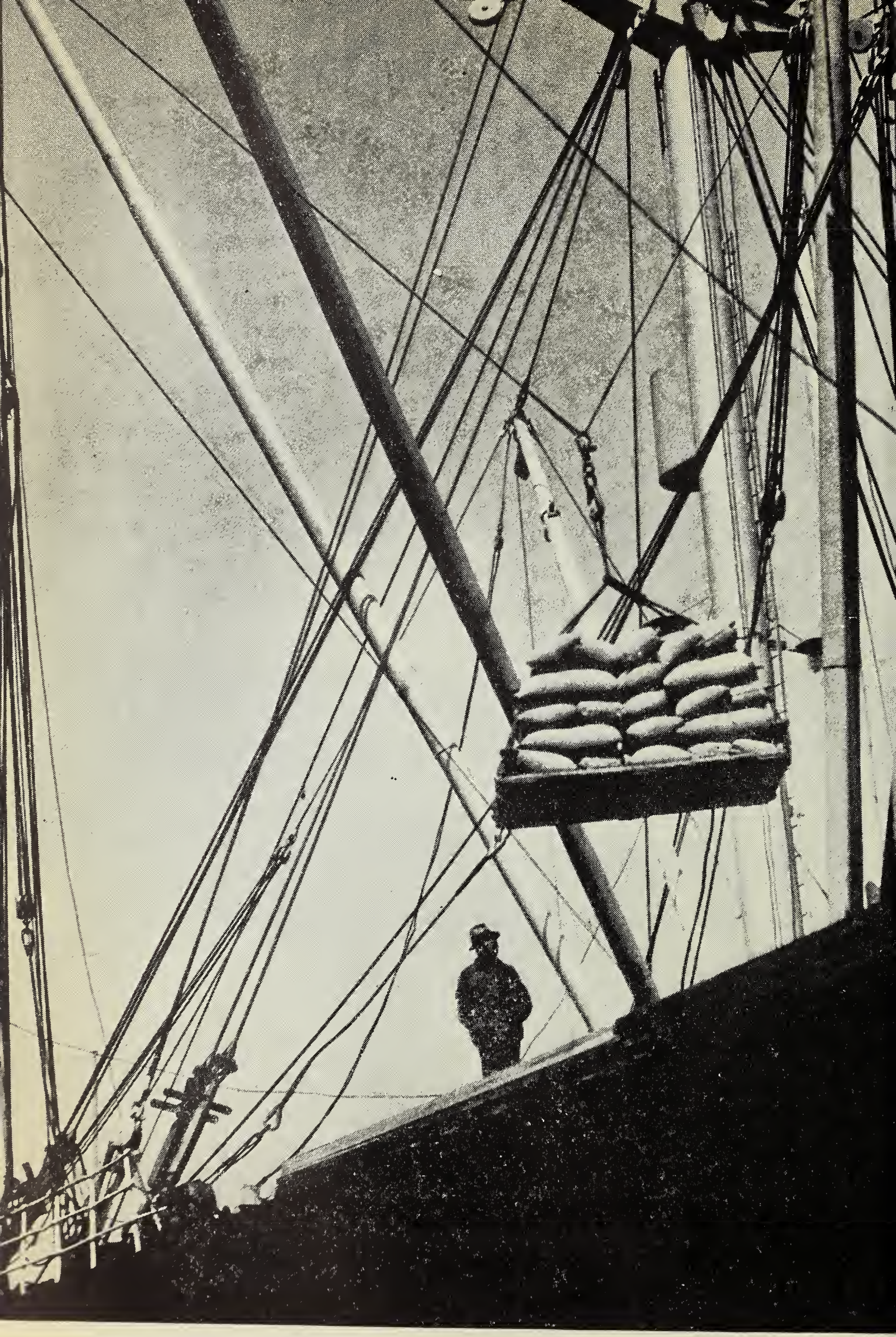
because the force moves twice as far as the resistance. This gives a mechanical advantage of 2 (if we disregard friction). In practical terms this means that with the help of movable pulleys a force of 50 pounds can lift a weight of 100 pounds.

Exercise. Rig up a small movable pulley, as shown on the opposite page. Use the same equipment that you used in the last experiment. How far does the one-pound weight move when your hand moves one foot? How much force was used? What is the mechanical advantage of the machine?

Block and Tackle. The third type of pulley, shown on page 235, is really a combination of pulleys which is known as block and tackle. Notice that in this machine double-grooved wheels are used, which make it possible to have four strands of rope between the two wheels, or *blocks*. Do you see, then, that when a weight is lifted by means of this machine, the force moves 4 times as far as the resistance? This gives a mechanical advantage of 4, which in practical terms means that (if we disregard friction) we can lift a 200-pound weight with a force of only 50 pounds.

Exercise. Rig up a model of a block-and-tackle machine, as you did for the other two types of pulleys. Estimate the mechanical advantage as you did before.

There are other ways of combining pulleys to increase the mechanical advantage, but the principle of work is always the same. Most cranes, hoists, and elevators use pulleys in one way or another. Painters use pulleys in regulating moving scaffolding on the sides of buildings, and sailors use pulleys to raise and to lower lifeboats on ships.



Rittase

How many pulleys can you find in this picture?

Exercise. Search your neighborhood and see how many different examples of pulleys you can find. See which member of the class can find the largest number.

The Wheel and Axle. Closely related to the pulley is the wheel and axle, an example of which is shown below. Other examples of this useful machine can be seen in the steering wheels of automobiles, in doorknobs and door keys, and in the keys which are used to wind clocks.

In this type of machine the force is applied on the rim of a wheel in a circular direction, and is used to move a weight or resistance which is attached to the axle of the wheel. Since the circumference of the wheel is greater than the circumference of the axle, the force moves farther than the resistance. A small force can therefore overcome a greater resistance.

Let us say that the circumference of the steering wheel on an automobile is 10 times the circumference of the axle of the steering wheel. Do you see, then, that if you turn the steering wheel round with a force of 10 pounds, you can overcome a resistance, or weight, of 100 pounds attached to the axle? In other words, the mechanical advantage of this type of machine is the ratio between the circumference of the wheel and the circumference of the axle (disregarding, of course, the work of overcoming friction).

The ship capstan is a simple example of wheel and axle

Sawders

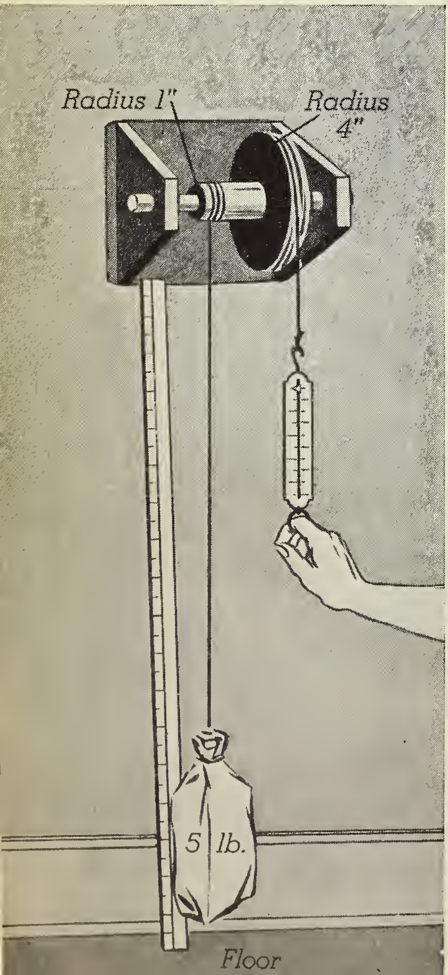
Exercise. Rig up a wheel and axle, as shown in the diagram below, and with the aid of a spring scales determine its mechanical advantage.

The Inclined Plane. Suppose the boy of the last section wanted to raise the large rock into a truck instead of just lifting it a few inches with a crowbar. He obviously would need more than the crowbar to help him accomplish this task. Among the simple machines which he might use for this purpose is the inclined plane. This machine is merely a sloping surface up which heavy objects may be pushed or rolled.

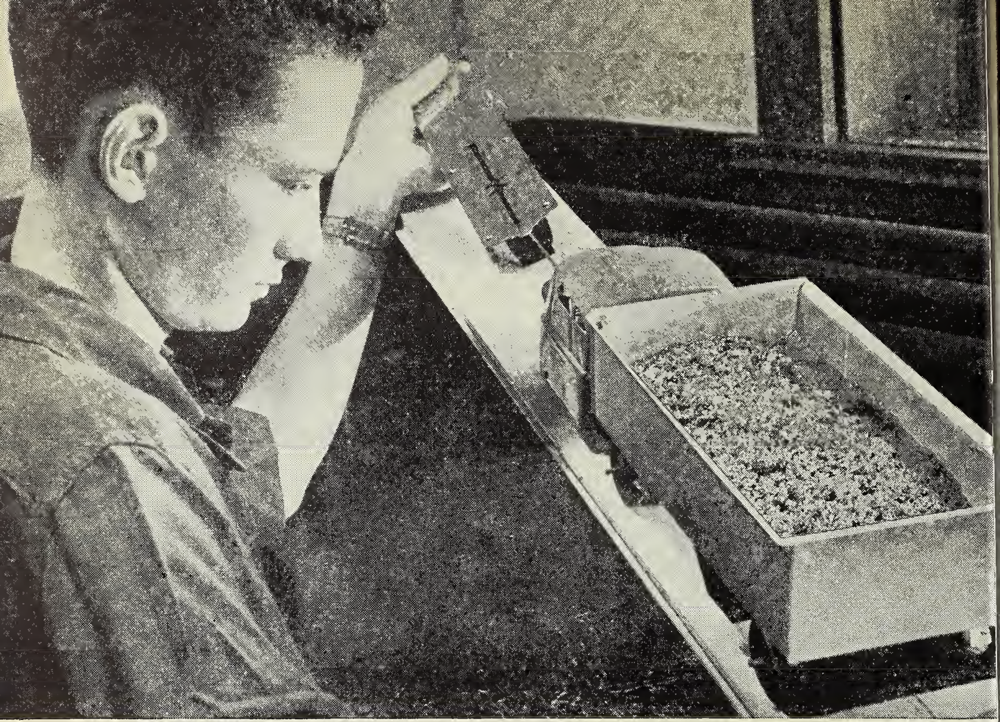
Let us say that the boy is able to load the heavy rock on a little cart with the aid of the crowbar. He will then be able to pull it up the planks which reach from the ground to the truck (see opposite page). Suppose it is 2 feet from the ground to the truck, and that the planks are 10 feet long. The force that the boy exerts on the floor of the cart in pulling it up this inclined plane acts through 10 feet, which is 5 times the distance that the rock must be lifted against the force of gravity. Do you see, then, that the mechanical advantage is 5 ($\frac{10}{2} = 5$)? If the cart with the rock weighs 300 pounds, the boy can roll it up the plane with a force of only 60 pounds ($\frac{300}{5} = 60$).

In other words, if we disregard friction, the mechanical advantage of

With this equipment you can determine the mechanical advantage of a wheel and axle



An inclined plane is very helpful in loading a truck



This boy is determining the mechanical advantage of an inclined plane

an inclined plane is equal to the length of the plane divided by the height (the vertical distance between the two ends). If the boy had used shorter (and therefore steeper) planks, the mechanical advantage would have been less and the boy would have had to push harder. If, on the other hand, the planks had been longer (and therefore less steep), the mechanical advantage would have been more and the boy would not have had to push so hard.

Exercises. Get a smooth board 4 feet long and wide enough for a toy cart or wagon to run on it, as shown above. Place the board on a table with one end 1 foot higher than the other end. Hook up the wagon to a spring scales, weigh it until it and its load weigh 1 pound, and measure the force which is necessary to pull the wagon (without jerking) up the board. What is the mechanical advantage of this inclined plane?

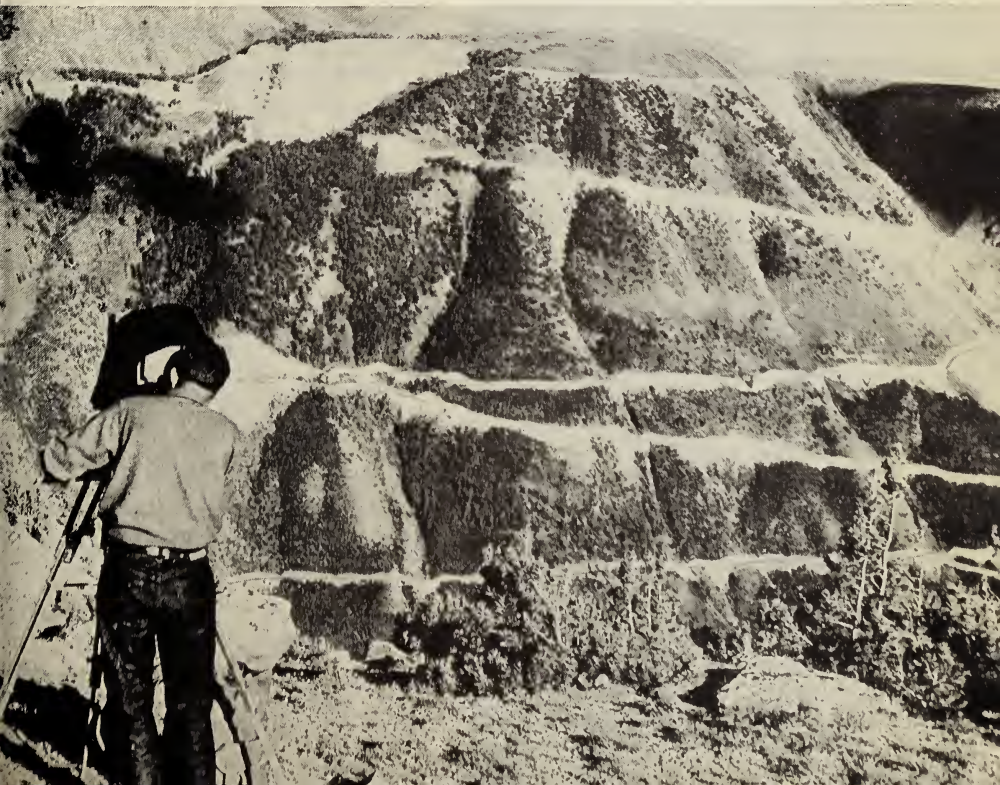
Change the slope of the board and the load of the wagon, and then measure the amount of force necessary to pull up the wagon. What is the mechanical advantage now?

Inclined planes are among the oldest machines used by man, and they are still in common use. Gangplanks into ships are a common use of the inclined plane, and so are the modern motor highways that "switchback" over the mountains (see photograph below). Can you name any other common uses?

The Wedge. The ax that the boy shown on page 244 is using is an example of another simple machine, which is

itchbacks" in the new highway from Red Lodge, Montana, to Yellowstone Na-al Park are inclined planes which enable automobiles to travel easily over some of the most rugged mountains on earth

Northern Pacific Railway



called a wedge. A wedge is merely a double movable inclined plane. When the boy swings the ax against the block of wood, he exerts a force on the handle which is less than the force of the blade as it pries the wood apart. But the handle moves through a much greater distance than does the blade, and that is why the blade can develop enough force to split the block of wood.

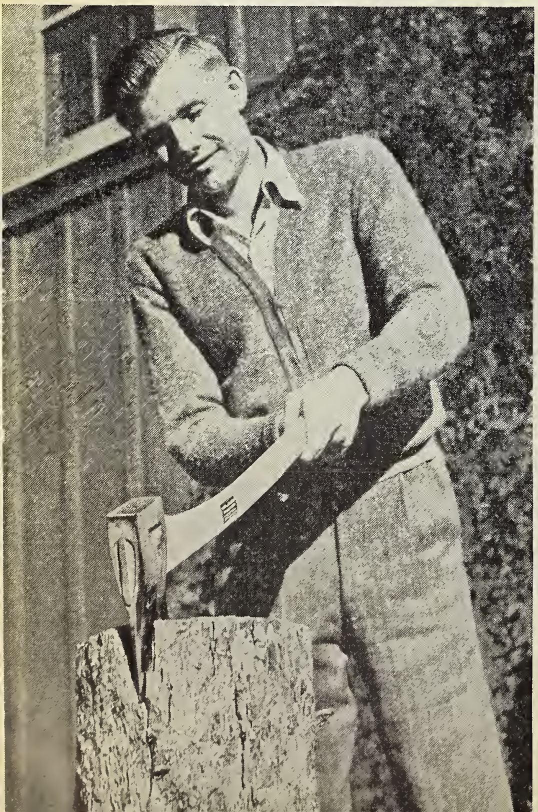
Wedges, in other words, are like all the other simple machines which we have studied in this chapter. They turn a small force working through a large distance into a greater force working through a lesser distance.

Exercise. How many types of wedges can you name?

The Screw. The last of the six fundamental machines is the screw. This machine, like the wedge, is really a special form of inclined plane. Look at an auger or an ordinary screw. Notice that it is merely a rod with an inclined plane wound spirally around it.

When screws are turned they are pulled into wood by means of their spiral ridges, or *threads*. As with all other machines, the mechanical advantage of the screw depends on having the force move farther than the resistance. The less inclined the threads of a screw, the greater is the mechanical advantage; the easier, in other words, can the screw be twisted into place.

The ax is a familiar example of the wedge



The propellers of boats and airplanes are special kinds of screws. They are made so that when they are turned they are twisted through water and air much as ordinary screws are twisted through wood.

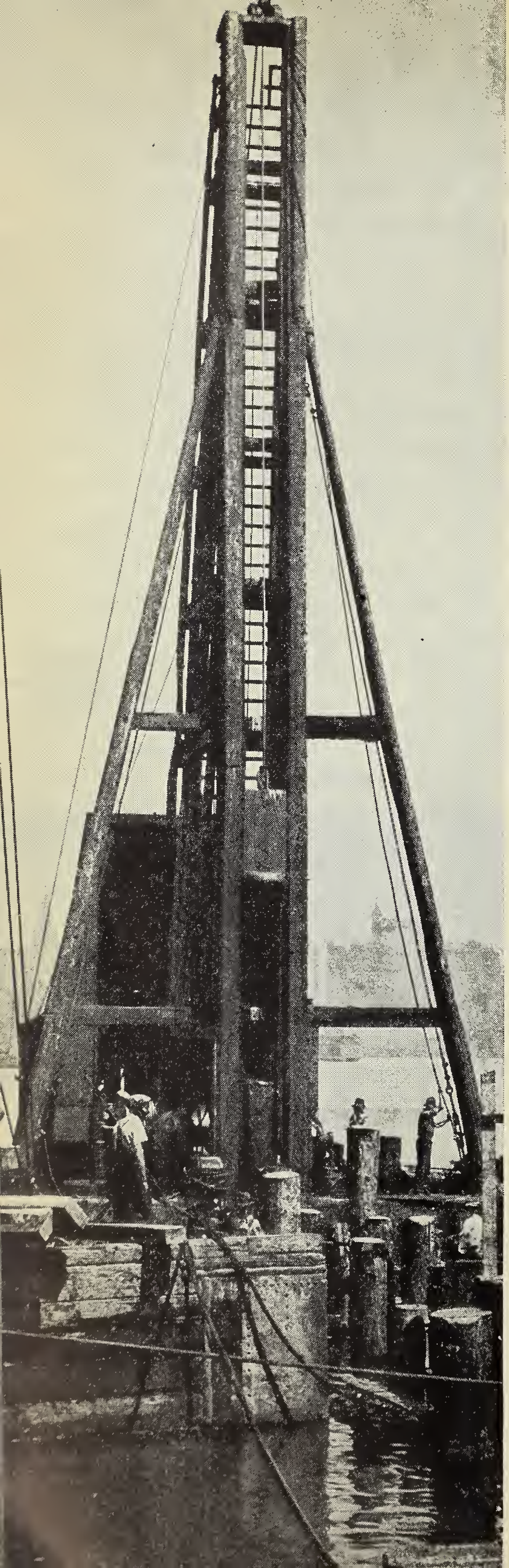
Exercise. How many other types of screws can you name?

Compound Machines. Compound machines are combinations of simple machines. Steam engines, gasoline engines, manufacturing machinery—all the complicated devices of the Machine Age—are combinations of levers, pulleys, wheels and axles, inclined planes, wedges, and screws. In all, forces are applied and resistances are overcome. As we go deeper into this unit we shall learn how some of these compound machines work.

Mechanical Energy. We began this chapter with a short discussion of energy. We learned that energy is that mysterious something which "makes things move their position or change their form." In the course of the chapter we learned how machines use energy by changing weak forces operating through longer distances into strong forces operating through shorter distances.

This energy which machines make use of is known as mechanical energy. Through ma-

The carpenter's brace and bit illustrates one of the many practical uses of the screw



chinery energy expresses itself in motion, and mechanical energy may be thought of as the energy of motion. Any moving object, whether it be a lever, a pulley, a wheel and axle, or a boulder rolling down a hill, possesses the energy of motion, which scientists call *kinetic energy*. They call it "kinetic" because this word comes from a Greek word meaning "to move."

Not all mechanical energy, however, is kinetic energy. If you pull up a weight with a pulley and hold it in mid-air, the weight has a kind of mechanical energy even though it is not moving. It has a stored energy which may be released if the pulley rope breaks and the weight crashes down to the ground. Such stored mechanical energy is called *potential energy*, the word "potential" coming from a Latin word which means "having power."

Galloway

The pile-driver is a machine that uses potential energy. Do you see how?

Potential energy, though not so obvious as kinetic energy, exists in many things. There is potential energy in a clock spring after it has been wound, energy which is slowly released to turn the hands of the clock. There is potential energy in gunpowder, which is rapidly released when the powder explodes. Notice that when potential energy is released it is turned into kinetic energy; it is changed, in other words, from stored energy into the energy of motion.

Exercise. How many examples of potential energy can you list?

Though mechanical energy is the most easily recognized form of energy, it is not the only form. In the following chapters we shall study some other important kinds of energy which are used extensively in the world of today.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. We speak of a push as "energy" and a pull as "force."

2. When we push on an object that will not move, we do work which can be definitely measured in terms of foot-pounds.

3. The force of gravity is a property possessed only by the earth, which enables it to keep loose objects on its surface from flying off into space.

4. When we say a boy weighs 120 pounds, we are giving a measure of his inertia.

5. Friction is the tendency of objects at rest to remain at rest.

6. Automobile manufacturers have tried to do away with friction between the car and the road, so that greater speed might be developed.

7. The fulcrum of a lever is always between the force and the resistance.

8. The advantage of the lever and all other simple machines is that more work can be got out of them than is put into them.

9. Crowbars, shovels, and axes are common examples of levers.

10. The single fixed pulley has the highest mechanical advantage of all the seven fundamental machines.

11. Movable pulleys, which are known as block and tackle, are really levers of the first class.

12. In a wheel and axle, the larger the axle in proportion to the wheel the greater is the mechanical advantage.

13. The mechanical advantage of an inclined plane is always the height of the raised end divided by the length.

14. The blades of a propeller are special types of wedges.

15. Potential energy is the energy of motion.

Questions for Discussion

1. May a fat person get tired "just carrying around his own weight"?

2. Why does it hurt worse when you catch your finger in the hinge of a door than when you catch it in the space by the latch?

Things to Do

1. Go on an exploration through your home in search of simple machines, paying special attention to the kitchen and the basement. List all the machines you find under headings for the six fundamental types.

2. Explain in terms of friction why it is more expensive to drive an automobile at fifty miles an hour than at twenty miles an hour. Consider tires, brakes, engine, and body in your answer, and also the necessity of starting and stopping the car.

3. Study the effect of gravity, inertia, and friction on your daily life, listing as many examples as possible of how they help and hinder you.

4. A boy pushing a wheelbarrow up a hill, a girl using a sewing machine, a woman turning a meat-grinder, are examples of the use of combinations of simple machines. Can you tell what simple machines are combined to do these three kinds of work? Find ten more machines which are combinations of simple machines, and tell what machines are combined.

CHAPTER NINE

How Do We Use Heat?

THE NATURE OF HEAT

What Radiant Energy Is. You have probably heard it said that the sun is a great source of energy. It sends out rays in all directions, some of which strike the earth. The energy that reaches us in the rays of the sun is known as radiant energy. On the earth this energy is changed into different forms, and one of these forms is heat.

Why Heat Is Energy. Coming from your studies on the energy of motion in the last chapter, you may not see why heat should be called a form of energy. A little observation, however, will show you that heat abundantly fulfills the requirements of energy: "to make things move their position or change their form."

The photograph on the opposite page illustrates a little instrument which you may have seen in the show window of a jewelry store. It is called a radiometer ("measurer of radiant energy"), and it operates in a very direct manner by means of the radiant energy of the sun. Notice that this instrument consists of a part that looks somewhat like a paddle wheel mounted inside a sealed glass container. One surface of each of the paddlelike blades is coated jet black; the other surface is bright. When the radiometer is placed in sunshine the wheel within it begins to turn. Why?

The secret of the radiometer lies in the fact that a black surface does not reflect the sun's rays, and that a bright surface does. On a black surface energy from the sun is turned into heat; on a bright surface it is reflected away.

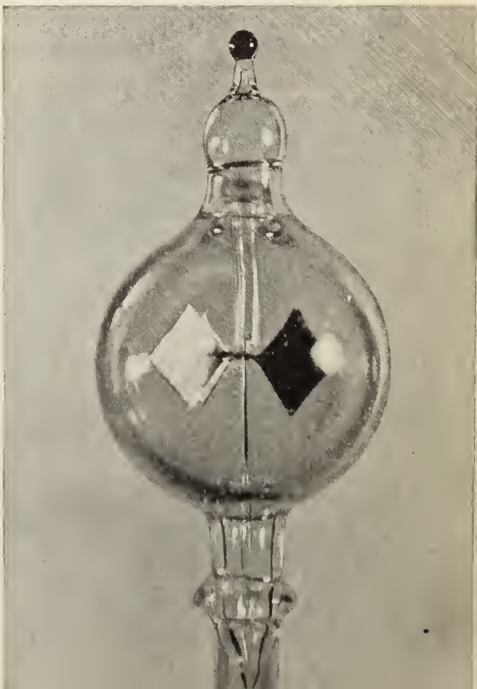
There is a little air in the glass container of the radiometer, and as this comes in contact with the blackened surfaces of the blades it is slightly heated. The result is that it expands and presses against the blackened surfaces with enough force to turn the paddle wheel. With radiant energy pushing in this way only on the blackened surfaces of the blades, the shaft continues to turn as long as it is in the direct rays of the sun.

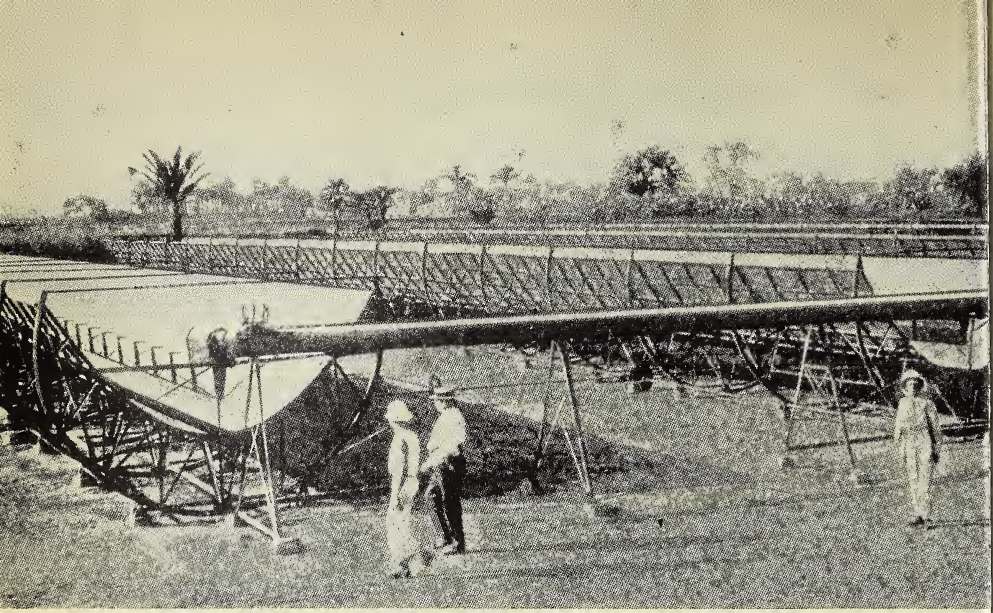
Almost anywhere you look you will see the same sort of thing taking place. Water evaporates from the surface of the earth because the sunlight that strikes it develops heat, and heat is energy which makes evaporation possible. Plants manufacture sugar and starch with the help of radiant energy, and these when eaten by animals or men are turned into heat which gives them the ability to be active. Coal and oil, which run so much of our modern machinery, are made of the plants and animals of earlier days. They are storehouses of radiant energy that can be changed into the energy of heat, which in turn can be made to run engines.

Do you see, then, that heat is an important form of energy; that it develops out of radiant energy and can be changed into mechanical energy which can be used to do a great variety of work?

Solar Engines and Cookers. Though the sun is the most important source of heat, we cannot widely use the rays of the sun as a direct source of this type of energy. The little ra-

The radiometer is a simple machine for using the radiant energy of the sun





Smithsonian Institution

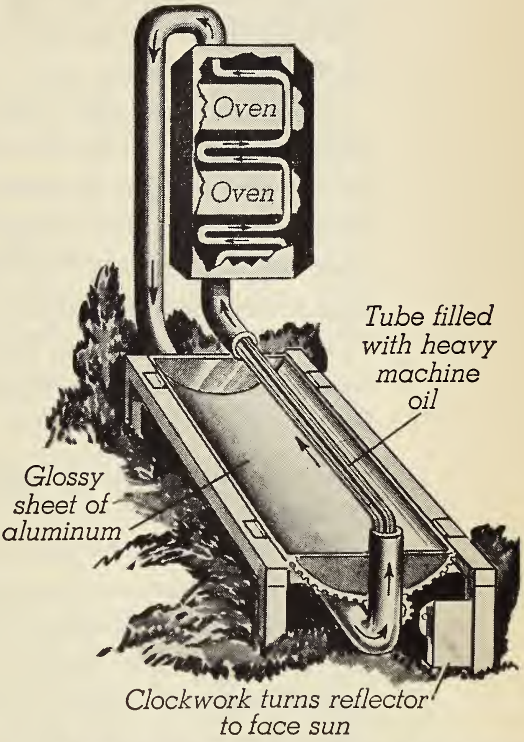
The great curved mirrors of this solar engine were designed
to change the radiant energy of the desert sun int

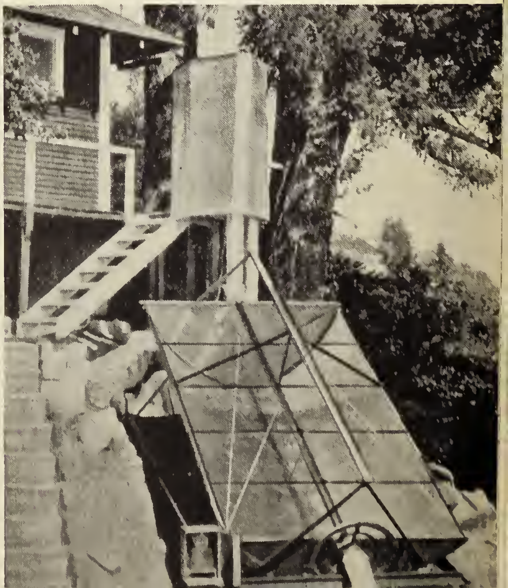
diometer in the jeweler's window uses radiant energy directly, but it is only a toy. A few solar (sun) engines have been invented for using directly the radiant energy of the sun, but they have not been very successful.

The photograph above is an illustration of such a solar engine that worked for a while in the Sahara Desert. The rays of the sun over a large area were focused by means of great curved mirrors upon pipes carrying water to the boiler of a small engine. The radiant energy, changed to heat, produced steam to run the engine, which in turn pumped water for irrigation.

Another illustration of the direct use of energy from solar radiation is found in the solar cooker. The one in the picture on the opposite page was made by Dr. C. G. Abbot, director of the Smithsonian Institution, who for many years has been experimenting with machines which use the energy of the sun. By using a glossy aluminum mirror in the shape of half a cylinder, he focused 90 square feet of sun's rays upon a tube 1¼ inches in diameter. The tube was filled with heavy engine oil. The sun's rays heated the oil in the tube and made it circulate as shown in the diagram. An oven was so constructed that oil circulated through pipes surrounding it. Carefully built to prevent the escape of heat, it remained hot enough through the night to be used for baking.

Here is Dr. Abbot's solar cooker (below) and how it works (above)


Oven
Oven
Tube filled with heavy machine oil
Glossy sheet of aluminum
Clockwork turns reflector to face sun



From these and other similar attempts we can come to the conclusion that there is really an enormous amount of energy in solar radiation. The disappointing feature of all the machines which have so far been invented to use solar radiation directly is the fact that the energy cannot be changed to heat without great loss. No inventor so far has been able to use much of the total energy of the sunshine. It is therefore not possible for these solar machines to compete with the much more efficient machines that use heat which comes from burning such substances as wood, coal, and oil.

How Fuels Produce Heat. In Chapter Seven we learned that substances which release heat energy by burning are called fuels. They are among our most valuable possessions because through them we can quickly release large amounts of solar energy that were stored up through many past ages. Through them we can get away from clumsy and inefficient devices for capturing solar energy directly.

Fuels are substances that readily and rapidly combine with the oxygen of the air and in doing so produce energy in the form of light and heat. *The process whereby a material combines with oxygen rapidly enough to produce light and heat is known as burning, or combustion.* Though heat is developed on earth in a variety of other ways, most of the practical uses for this form of energy are based on combustion. Let us see what these uses are.

THE USE OF HEAT IN THE HOME

The Importance of Heat Transference. One of the chief uses of heat today is in warming houses and other buildings where civilized men spend a large percentage of their lives. All over the world people sit comfortably in well-heated schools, theaters, offices, factories, churches, and homes. They do so because man has learned how to develop and control heat for his own comfort and health.

The use of heat in buildings depends first on a thorough understanding of how heat may be transferred from place to place. In earlier work in science you have probably learned that the distribution of heat takes place by three different processes: radiation, conduction, and convection. Let us briefly refresh our minds on these processes before we study how men have used them to improve the conditions of their lives.

Radiation. We have seen how radiant energy shoots out in rays from the sun, and turns into heat when it strikes objects on the surface of the earth. In the same way radiant energy may shoot out from a campfire or any other hot object, and then turn into heat when the rays strike near-by objects. We speak of this type of heat distribution as radiation.

One strange thing about heat rays is that they pass through certain materials without heating them. On a winter's day the air on the porch may be well below 32° F., the freezing point of water, yet the snow on the sidewalk is melting. On a summer's day the metal body of an automobile exposed to the sunshine may be hot enough to burn you, though the air around it is relatively cool. These examples prove that heat waves pass through air without heating it very much, and give up their heat only when they strike objects through which they cannot pass.

Exercise. Can you think of any other substances that radiant heat passes through without heating very much?

Conduction. A second method of heat transference may be observed in many everyday occurrences. The spoon with which you stir a hot liquid becomes warm, first the end that is in the liquid and later the end that extends out into the air. The poker that you warm up in a fire at one end gradually becomes warm at the other end. The air over a hot radiator gets warm in much the same way. Heat, in other words, tends to move from the warmer to the cooler end of an object and from a warmer substance to a cooler substance that is touching it. This method of heat transference is called conduction.

You have no doubt observed that some substances are better conductors of heat than others. Metals, on the whole, are the best conductors, gases the poorest. Poor conductors are useful in keeping heat from escaping out of pipes, houses, and other places where we wish to confine it, and when used for this purpose are known as *insulators*. Asbestos is a fine insulator, and so are the cotton and wool garments which we use to prevent our body heat from escaping into the air.

Exercise. How many good conductors of heat can you name? How many good insulators?

Convection. You have probably observed many times that when materials are heated they grow larger, or expand; that when they are cooled they grow smaller, or contract. When the gases of the air are heated, they expand, grow lighter, and are forced to rise by the colder, heavier air below, as you may prove if you drop a small piece of tissue paper over a hot stove. As heated air continues to rise cooler air continues to move in to take its place, with the result that heat is distributed. This is the commonest and

Heat from an open fire (left) reaches you chiefly by radiation. Convection curren heated air rise above your head and are lost. The fireplace (right), like the bo heats chiefly by radiation. The convection currents of heated air escape up the chi

Galloway

Lambert

most important type of heat transference on the surface of the earth, as we shall see as we go on with this chapter. It is known as convection.

Heating by an Open Fire. You have no doubt stood near an open fire out of doors. You know that at best this method of heating is not very satisfactory, for you "roast on one side and freeze on the other." Why should this be? The answer is that you are receiving heat mainly by radiation. Convection currents are set up but the heated air is forced upward away from you. Thus the heated air does not circulate in such a way as to warm you. Similarly, with a fireplace, the heated air is forced up the chimney; most of the heat you receive is what radiates in your direction.

How a Stove Warms a Room. The illustration below shows the kind of stove which was once widely used to fight the winter cold. When the stove is heated, the air around it grows warm and light. It rises toward the ceiling as cooler air moves in to take its place. This air in turn is heated; it rises and more cool air moves in. If there is not too much loss of heat through cracks or doors and windows, the temperature of all the air in the room will rise rapidly as the air continues to flow by convection towards and away from the stove.

The old-fashioned stove, which heats chiefly by convection, is an economical way of heating a single room

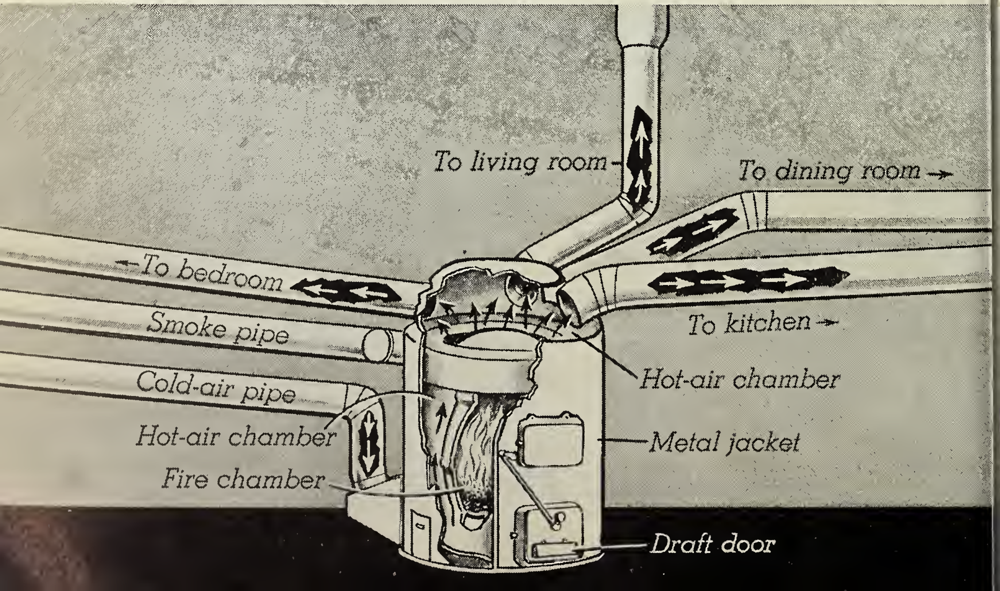
Galloway

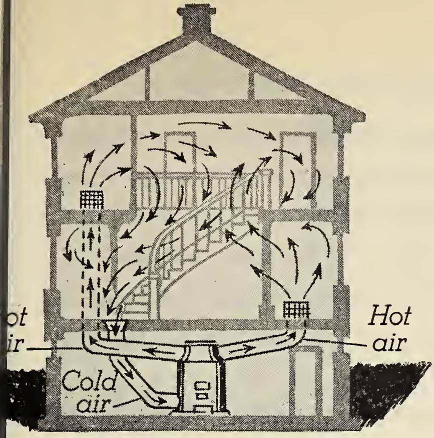
A stove is the most efficient heater for a small room because it delivers more heat to the room from a pound of coal than any other heater in common use. The difficulty, however, is that it satisfactorily heats only one room. As houses grew larger, other ways of heating had to be found.

The Hot-Air Furnace. The simplest way of heating houses with more than one room is by means of a hot-air furnace. Such a furnace is shown below. Notice that this furnace is really an old-fashioned stove enclosed by a metal jacket. This jacket has an opening at the bottom into which cold air enters through a large pipe. The heat from the fire in the stovelike portion of the furnace heats this cold air and causes it to rise into the pipes which lead to the rooms above.

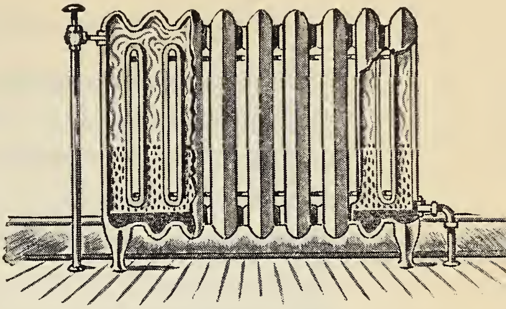
The diagram on the opposite page shows how convection currents are set up by the furnace and how they circulate through the house. In the simplest type of hot-air furnace (the pipeless furnace) the top of the furnace is placed level with the floor of a room on the ground floor of the house. The heated air flows into the room directly from the space

The hot-air furnace, suitable for heating small houses, is a development of the old-fashioned stove. This diagram explains how it wo





We see from this diagram how convection currents are set in motion by a hot-air furnace to heat a small house



Steam heats this radiator, turns into water, and flows back to the boiler, where it is turned into steam again. How does this differ from what happens in the radiator of a hot-water-heating system?

between the stove and the enclosing jacket and circulates through the house without the help of pipes.

While the hot-air furnace has certain advantages, it also has definite disadvantages. The heated air cools very rapidly as it leaves the hot-air box, with the result that upper-floor rooms may be cold. Also, the rooms on the windward side of the house are likely to be hard to heat. Then, too, the registers through which the heated air reaches the rooms furnish excellent openings for dust and dirt. Nevertheless, many hot-air furnaces are in use because they are both economical and simple to operate.

The Hot-Water Heating System. Another system of heating is the hot-water plant diagramed on page 261. Here the furnace, instead of heating air, heats water. The heated water in the boiler is lighter than cold water, with the result that the hot water is forced upward through pipes into the radiators by the heavier cooled water that flows to the furnace through the return pipe. Heat keeps the water flowing through the radiators as the convection currents of water continue to move through the pipes.

The radiators, usually made of iron, offer heating space, as shown on page 259. As the hot water flows through each radiator, heat is transferred from the water to the iron casing of the radiator by conduction. It is then radiated into the room and distributed by convection currents set up in the air. Do you see that in this kind of heating all types of heat transference are used?

Certain precautions are necessary with the hot-water heater. Obviously, water must be provided at all times. Moreover, if the fire gets too hot, the water changes to steam. Notice in the diagram on the opposite page that a box called an expansion tank is shown in the basement. As the water is heated, it expands. The expansion tank is connected with the pipes so that as the water expands the extra water flows into the tank. With this precaution the pipes are in no danger of bursting, even when the water gets hot enough to develop steam.

Like the hot-air furnace, the hot-water heating system has both advantages and disadvantages. Heating by hot water is efficient, and it provides a more even temperature than any other type of plant. It is expensive to install, on the other hand, and slow to deliver its heat. On the occasional damp, cool days of spring and fall, it is a slow and clumsy device for taking the chill off a house.

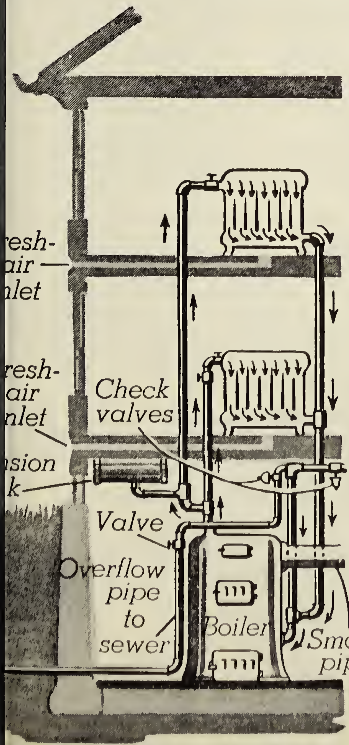
The Steam Boiler. The last of the three common types of modern heating plants is the steam boiler diagramed on the opposite page. Notice that this heating plant looks something like the boiler of a steam engine. Unlike the hot-water boiler just described, the steam boiler is kept only partly filled with water. This is steadily changed into steam with force enough to rise through pipes into radiators which are distributed through the house.

In the radiators the steam turns back into water, heating the radiators while doing so. This water then returns to the boiler, where it is turned into steam again. The radiators heat the rooms by radiation and conduction in the same way that the radiators of a hot-water system do.

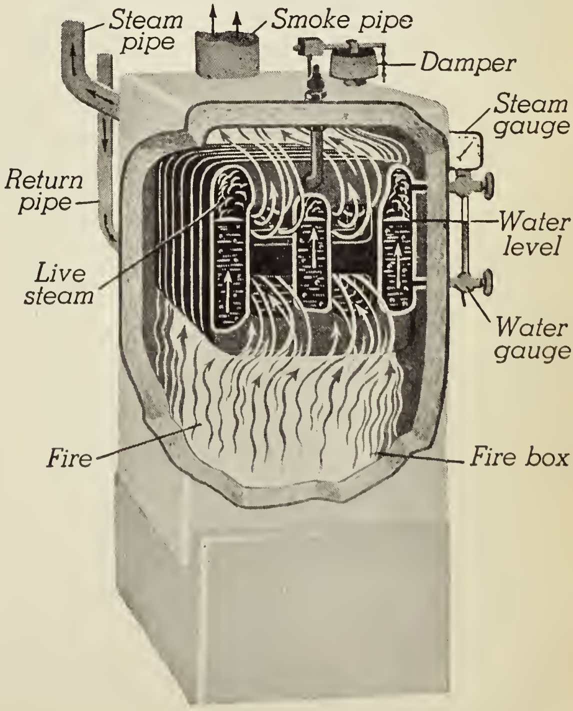
Exercise. List the features in which a steam-heating system resembles, and those in which it is unlike, a hot-water system.

A steam-heating plant costs more to install than a hot-air plant, but less than a hot-water plant. It probably gives more heat for the fuel consumed than any other type of system excepting the common stove. On the other hand, its heat is uneven, like that of the hot-air furnace; and it provides no means of ventilation. In houses with steam heat or hot-water heat, ventilation may be had only by opening windows or by installing special inlets for the en-

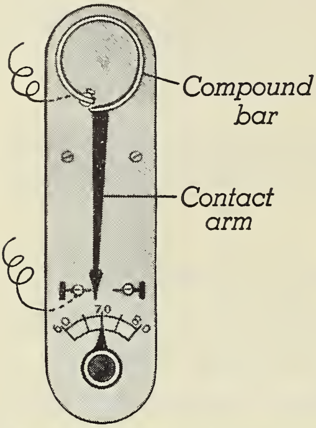
is diagram shows how a hot-water heating system operates



This is what happens in the boiler of a steam-heating plant



trance of fresh air, as shown in the first diagram on page 261. In houses with hot-air heating this problem is much less serious. Do you see why?



The thermostat regulates heat

Exercise. Make a careful study of the heating plant in your home. With the help of the diagrams in this chapter, make a diagram of your own heating plant and label all important parts. What are its particular advantages and disadvantages?

Control of Heat in the Home. Today many homes are equipped with furnaces or boilers which operate automatically. A *thermostat*, or heat control, is a mechanism which controls the air that the fuel must have in order to burn. It is fastened to the wall of a room in the house. It opens the air drafts of the heating plant in the basement as the house gets cooler and closes them as the house gets warmer, thus fanning and checking the fire as the need arises.

The diagram above shows the working parts of a thermostat. The *compound bar* operates on the principle that materials expand when heated and contract when cooled, but *not to the same extent*. It is made by fastening together strips of copper and iron, which do not expand and contract at the same rate. Copper when heated expands more than iron. The result is that when the compound bar in the thermostat is heated, the end attached to the contact arm moves a little to the left because the copper which is on the outside of the curve pushes in that direction. As the bar is cooled, it moves the contact arm a little to the right.

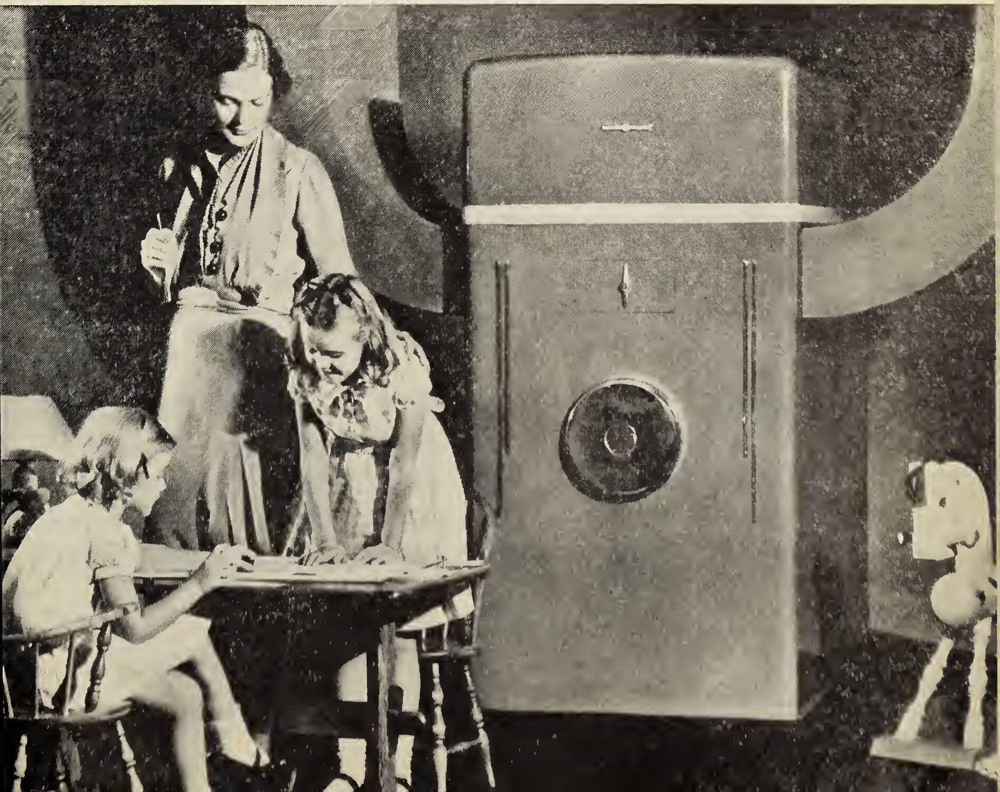
Exercise. Get a thin strip of copper and a thin strip of iron and have them riveted together in a machine shop. Heat one end of this bar in a flame until it becomes curved. Is the copper on the inside or the outside of the curve? Why?

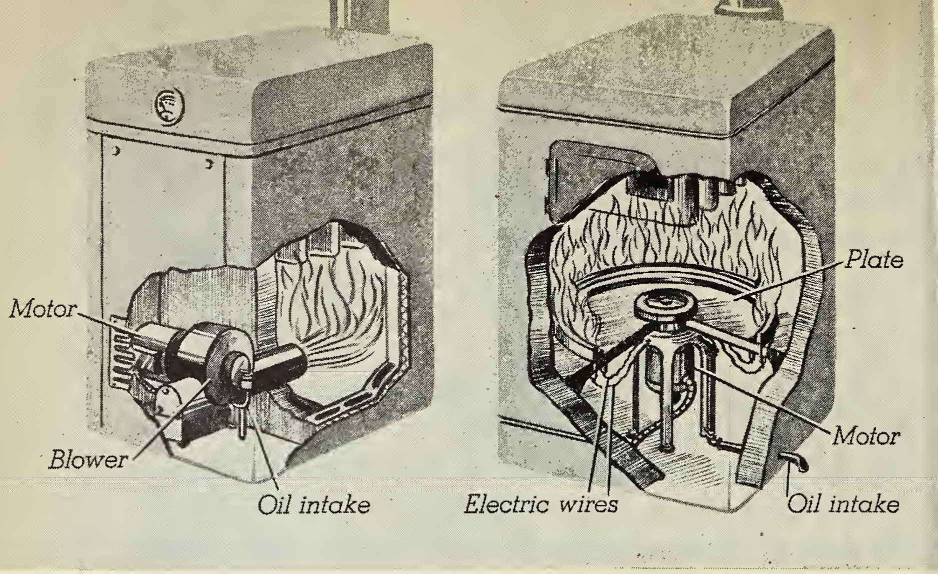
When the room has cooled to the temperature for which the thermostat is set, the contact arm touches the point on the right. This contact carries an electric current through an electric motor and opens the draft of the furnace. As the room gets warmer, the compound bar pushes the contact arm to the left. When contact is made on this side, an electric current again goes through the motor, but this time in such a way that the motor closes the draft of the furnace.

Of fuels used for heat, the most common, of course, is

lern heating and air-conditioning systems are so clean and compact that the basement may become part of the living space of the house

Galloway





This is how the "gun" type (left) and the rotary type (right) oil-burners work

coal. Another type of fuel, however, is rapidly coming into common use. Many homes are now equipped with oil-burners, which use a heavy and comparatively cheap type of fuel oil. The machines are, in general, of two types. In one (see above) the oil is changed into vapor and fed through the nozzle of a "gun." In the other type the oil is fed to a rotating plate which throws the oil in a circle around the firebox.

In any form of heating, it is chiefly convection currents that distribute the heat through the house. Because the walls of houses are not airtight, cold air seeps in from outdoors. The force of the air currents in any particular house depends mostly upon the difference in temperature between the indoor and the outdoor air. How fast do you think air changes in an ordinary well-built house when the temperature indoors is 70°, the temperature outdoors is 0°, and the doors and windows are tightly closed? According to estimates the air passes through walls and crevices fast enough to accomplish a complete change of air every hour! Do you see then why house-heating is one of the main expenses of life in cold climates?

Exercise. Heat is also widely used in the home to supply hot water for washing and in some types of refrigerators. Look up in a textbook of physics or an encyclopedia how these devices work, and make a report on them to your class.

HOW WE MAKE HEAT PERFORM WORK

Making Steam Work. In the last section we saw that the effectiveness of modern heating plants depends on the fact that air and water expand when heated. Because of this fact the convection currents that heat our homes are made possible. The expansion of air and water with heating is the basis of many other practical uses of heat energy in the modern world. Indeed, it is the basis on which much of the world's work is done, as we shall now see.

In the little radiometer in the jeweler's window we caught a glimpse of how the radiant energy of the sun can be changed into the energy of motion. When the air near the blackened surfaces of the paddles was heated, it expanded and pushed the wheel around. Radiant energy was turned into heat energy, which in turn was changed into mechanical energy. The same principle underlies the operation of the steam-driven machines which harness the energy of heat for a great deal of useful work.

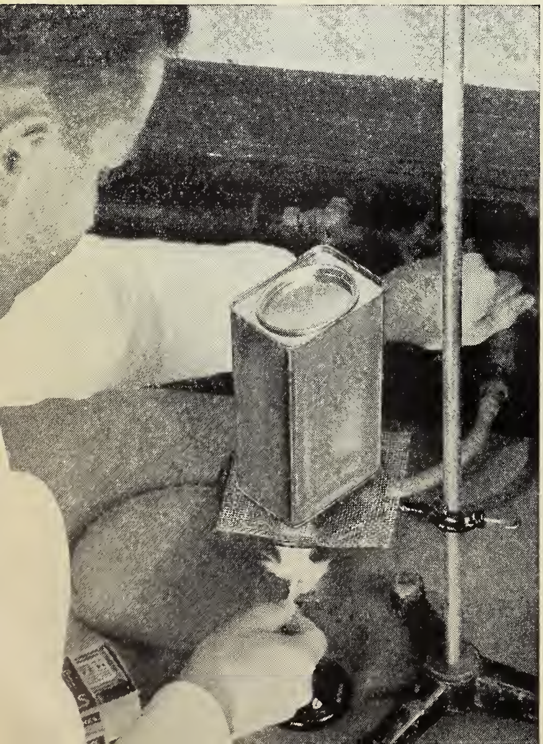
Exercise. How to show the way steam performs work: Get a cocoa or sirup can or any other type of can with a friction top. Put a little water and a few stones in the can and then squeeze the top in place, but not too tightly. Heat the can as shown on page 266, being careful to stand at a safe distance. What happens when steam forms in the can? Where does the energy responsible for what happens come from?

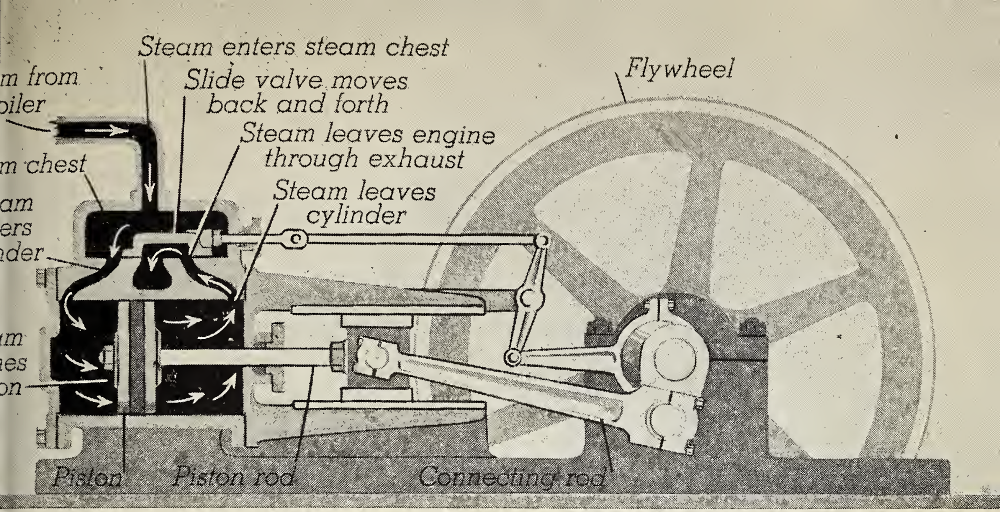
The Steam Engine. Just as in the above experiment, heat is used in the modern steam engine to turn water into steam. Confined in a boiler, the steam from boiling water develops great pressure on the walls that confine it. If this steam is then allowed to escape slowly, it expands with great force which is capable of doing much work.

The diagram on the opposite page shows how a steam engine makes the force of expanding steam perform work. Notice that steam develops from heat which is applied to the water in a boiler. When enough steam has developed, the pressure is great enough to force the steam into the *steam chest* of the engine, and then through the *slide valve* into the *cylinder*. Inside the cylinder the steam pressure acts as a force against the *piston*, with the result that the piston is pushed toward one end of the cylinder. The *piston rod* is attached to the *flywheel* so that when the piston moves it causes the flywheel to turn.

But why does the piston move back and forth? Study carefully the slide valve shown in the diagram. Notice that there are openings for steam to enter into each end of the cylinder, and that the piston slides back and forth between these two openings. In the

This boy is demonstrating how steam can be made to perform work





The diagram above explains how a steam engine makes steam perform work

diagram, steam pressure is driving the piston from the left toward the right. As soon as it reaches the right end of the cylinder, the piston starts back toward the left.

The slide valve makes it possible for the piston to move in this fashion. Notice that this valve is joined to the flywheel with rods. By means of the rods the motions are timed in such a manner that the slide valve is moved toward the left before the piston reaches its position farthest toward the right. This closes the opening between the steam chest and the left-hand side of the cylinder, and at the same time opens the valve between the steam chest and the right-hand side of the cylinder. Pressure from the steam now drives the piston back toward the left, and the slide valve reverses its action. The used steam is forced out through the exhaust.

Why is it necessary for the steam engine to have a heavy flywheel? The answer is that the flywheel makes the engine run more smoothly, particularly when it is suddenly made to do an increased amount of work. Because it is heavy, the inertia of the flywheel tends to keep it turning and thus tends to keep the piston moving smoothly when anything interrupts or slows down its movement.

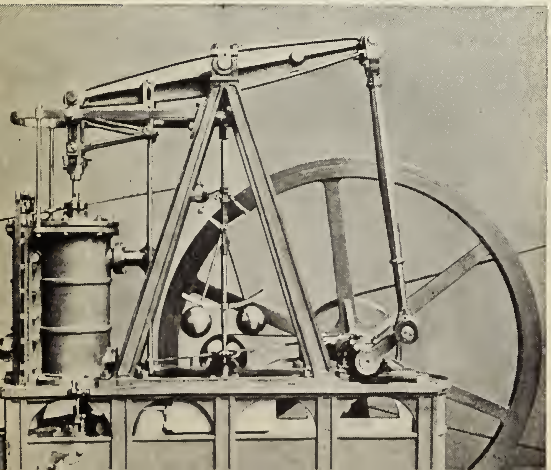
Exercise. Get a small toy steam engine and turn the flywheel until the slide valve is in a position to allow steam to enter one end of the cylinder. Then turn the flywheel farther until the slide valve is in a position to allow steam to enter the other end of the cylinder. Study the slide valve and the rods with which it is connected to the flywheel until you understand exactly how they act.

Though the ancients knew something of the strength of expanding steam, the first practical steam engine was not put into use until 1769. In that year James Watt patented the engine pictured below. Since then steam engines have been hooked up to a great variety of machinery for performing a great variety of work. They have been used to pump water from mines, to run machinery in factories and on farms, to drive ships through the water and locomotives over the land. The industrial life of the civilized world was greatly changed by this single invention, as we shall see in a later chapter.

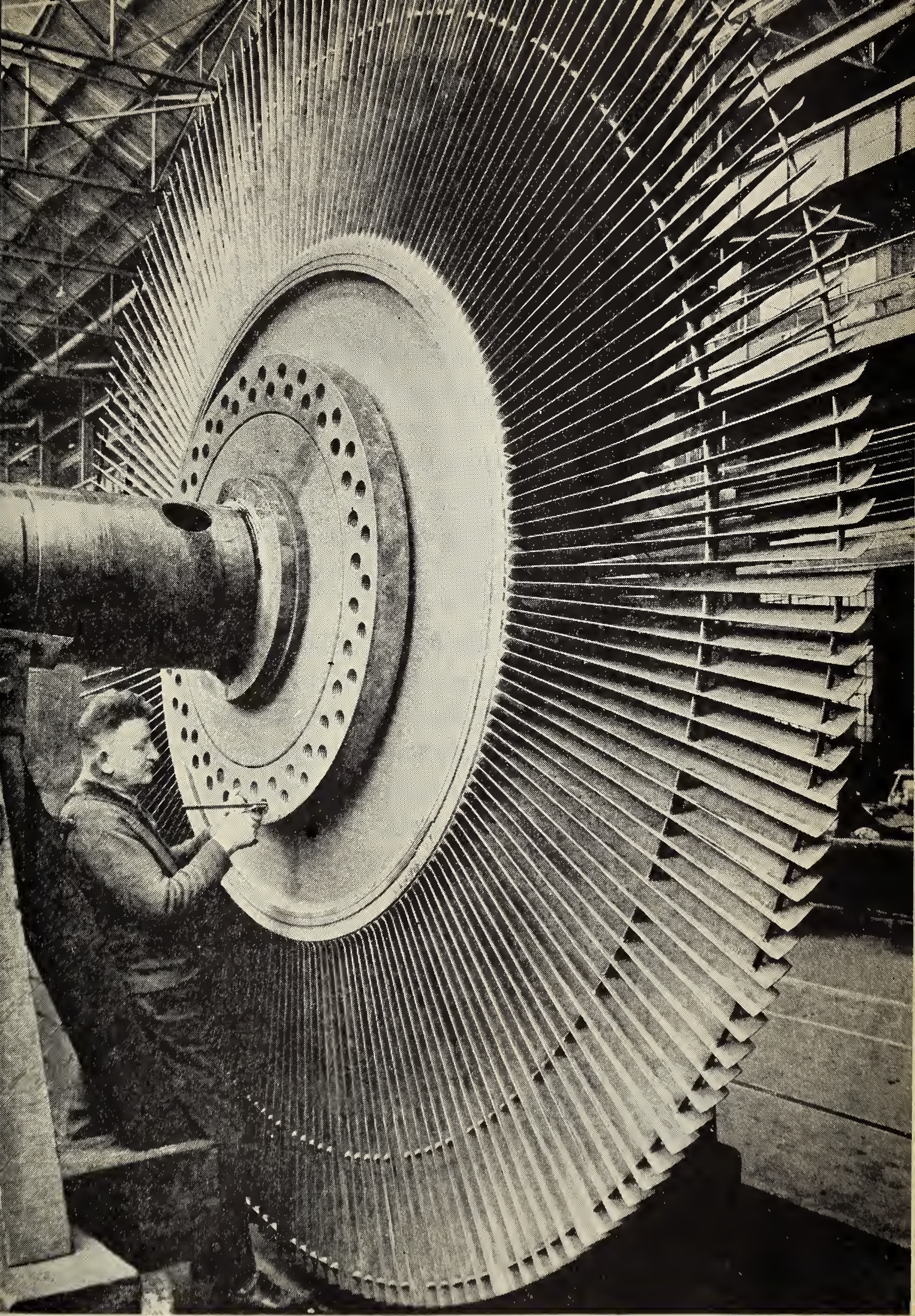
The Steam Turbine. If you were to visit a large electric power plant, you would find that the steam engines used there are of an entirely different type from the one we have just described. The steam, instead of being used to move pistons back and forth in cylinders, is used to spin huge wheels. Such engines are known as steam turbines.

Watt's steam engine was crude, but it changed the industrial life of the civilized world

Compton's Pictured Encyclopedia



Exercise. Demonstrate the principle of the steam turbine by the simple means shown on page 270. The blades



Westinghouse

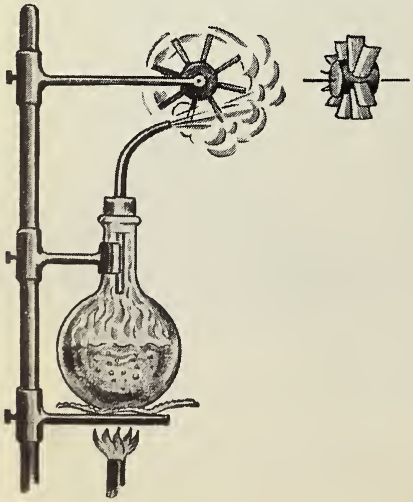
n at high pressure strikes the blades of this steam turbine with force enough to make the tips move nearly as fast as a bullet may be cut from a piece of tin and inserted into a wheel made of a large cork or wooden spoon. A darning needle may be used as an axle. Set up the wheel as shown, and see that it turns easily before applying steam from the heated water in the flask. Be careful not to heat so rapidly that the stopper is blown out.

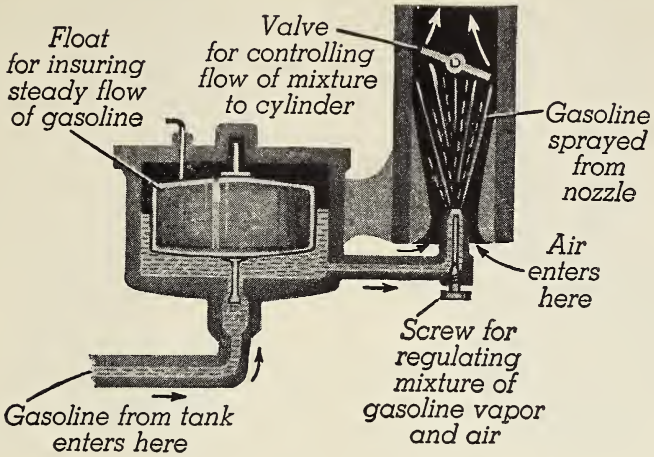
In practice, of course, the steam turbine is a very complicated piece of machinery, as the photograph on page 269 will indicate. The blades are set very accurately and mounted on a rotating wheel. The moving parts are enclosed by a case. Steam under high pressure issues from the boiler of the turbine engine as a continuous jet, and this jet strikes against the blades, causing the turbine wheel to spin.

The efficiency of the steam-turbine engine is greater than that of an engine using cylinders, because the loss of energy is less in the turbine than in the cylinder engines. Steam turbines are accordingly very widely used. They are particularly useful in steamships, not only because they are more efficient, but because they run with very little vibration.

The Internal-Combustion Engine. The gasoline engine, like the steam engine, was a great step forward in the control of energy. The forces that run the gasoline engine come from explosions which take place inside the cylinders. It is called an *internal-combustion engine* because the combustion, or burning, of the fuel goes on inside the cylinders. It is therefore fundamentally different from the steam engine,

This is a homemade steam turbine




Float for insuring steady flow of gasoline
Valve for controlling flow of mixture to cylinder
Gasoline sprayed from nozzle
Air enters here
Screw for regulating mixture of gasoline vapor and air
Gasoline from tank enters here

The carburetor mixes gasoline vapor with air

which is an *external-combustion engine* because the combustion takes place in a boiler outside the cylinders.

An explosion is merely a rapid burning and a sudden release of energy. You may be familiar with the explosion of hydrogen that takes place when a match is applied to a mixture of hydrogen and air in a glass bottle or a test tube. A mixture of gasoline vapor and air will explode in the same way. Gasoline is a liquid, but it evaporates rapidly and changes to vapor. In this form it will mix with air and burn with a sudden explosion.

How Gas and Air Are Mixed in a Gasoline Engine. Like a steam engine, a gasoline engine consists of cylinder, piston, rods, and flywheel. Unlike a steam engine, a gasoline engine must have some mechanism for combining gasoline vapor and air in an explosive mixture. The mechanism for accomplishing this task is called a *carburetor.*

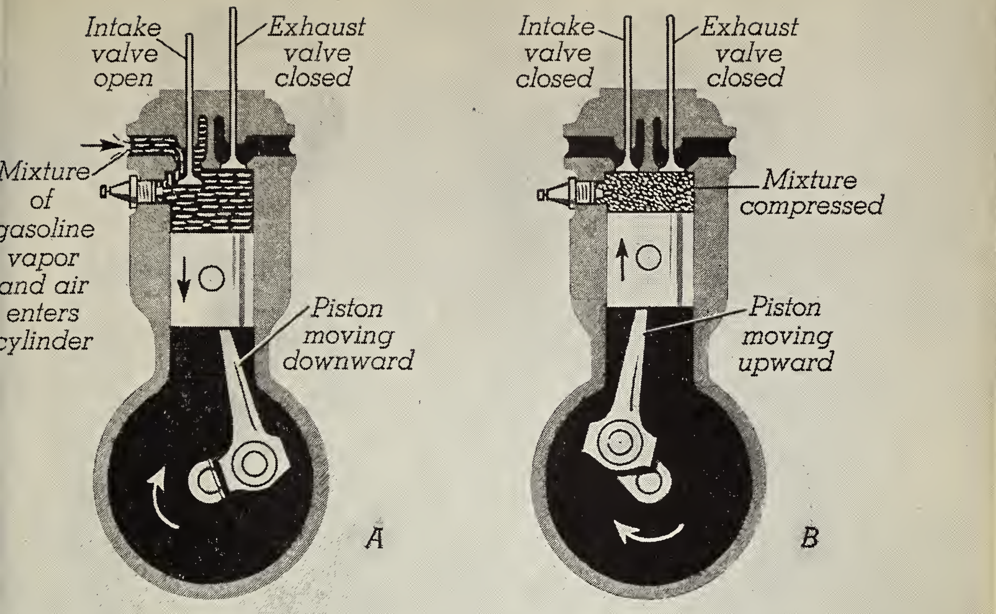
Above is a diagram that shows how a carburetor works. Notice that the liquid gasoline is fed to the cylinder of the engine through a little nozzle that works very much like a throat spray or Flit gun. Air and gasoline are mixed together in a highly explosive vapor which is sprayed into the cylinder. Notice the screw for regulating the proportions of this mixture. When the carburetor is correctly adjusted there are about 16 parts of air to 1 part of gasoline vapor. A mixture with these proportions gives the most powerful explosion.

What Happens Inside the Cylinder of a Gasoline Engine. The illustrations on the opposite page show what happens to the mixture of gasoline vapor and air after it enters the cylinder of the engine. In *A* the mixture is moving through the intake into the part of the cylinder that lies above the piston. It is doing so because the piston is moving downward and making a partial vacuum in the cylinder. Outside air pressure forces the gas-air mixture into the cylinder to fill up this partial vacuum. This downward stroke of the piston, which brings fuel into the cylinder, is called the *intake stroke.*

Just before the piston starts upward again, as shown in *B*, the intake valve closes, so that the mixture of gasoline vapor and air cannot escape. The rising piston squeezes, or compresses, the mixture into a very small space. When the piston reaches the end of its upward movement, this so-called *compression stroke* comes to an end.

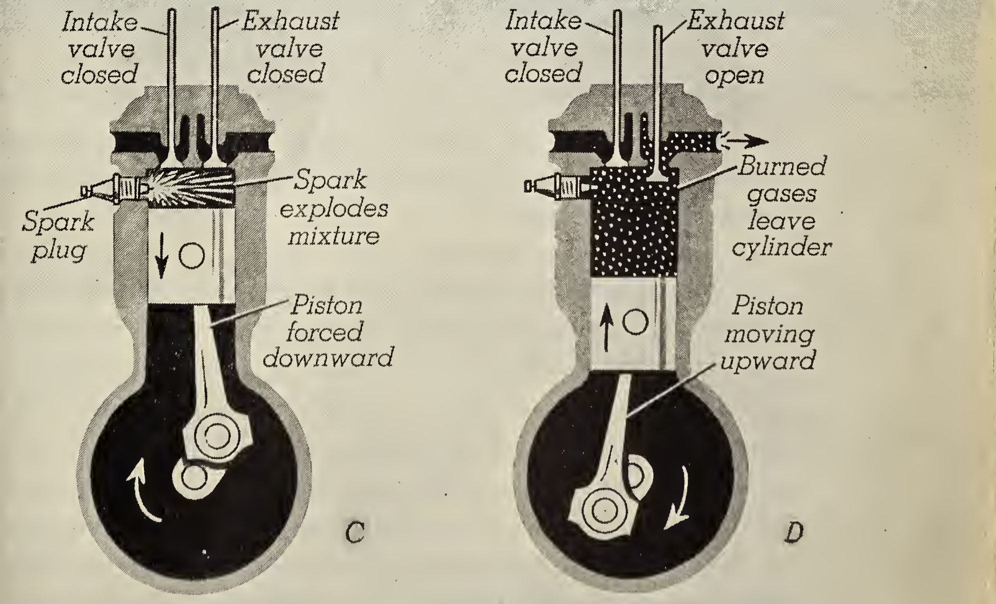
Just after the piston starts downward again, as shown in *C*, an electric spark jumps across the gap between the two wires at the end of the spark plug. This explodes the mixture and drives the piston downward with great force, in what is called the *power stroke.*

As the piston starts upward again, as shown in *D*, the exhaust valve opens and the gases left from the explosion



Intake

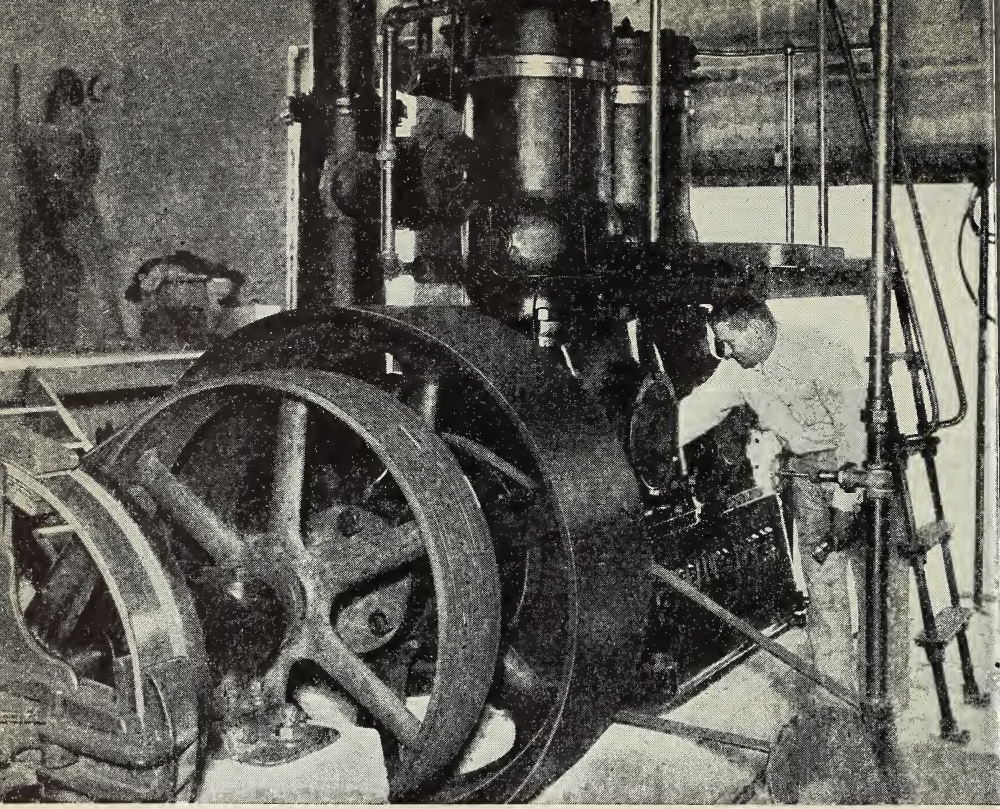
Compression



Power stroke

Exhaust

These diagrams explain the action of a four-cycle gasoline engine



Gendreau

The Diesel engine is rapidly increasing in popularity

are forced out of the engine. At the end of this so-called *exhaust stroke,* the exhaust valve closes and a new series of strokes begins.

Types of Gasoline Engines. The engine described above is known as a four-stroke, or more generally as a *four-cycle,* gasoline engine. Because the piston of such an engine gets a push only once in every four strokes, it is apt to work unevenly. To make it less jerky a heavy flywheel is attached, whose inertia tends to smooth out the unevenness of the moving piston just as in the case of the steam engine.

A good way of improving the performance of a gasoline engine is to increase the number of cylinders. In this way vibration and jerkiness are greatly reduced, and the amount of work which the engine can do is greatly increased. Though a few one-cylinder gasoline engines are in use today for pumping water and running outboard motors for small boats, most engines of this type have several cylinders. Most automobiles engines have four, six, or eight cylinders. Airplane motors may have nine or twelve.

The Diesel Engine. Just as the steam turbine was a great improvement over the steam engine, the Diesel engine was a great improvement over the gasoline engine. Like the gasoline engine, the Diesel engine is of the internal-combustion type, but it burns fuel oil instead of gasoline. When you see a modern streamlined train racing across the landscape at ninety miles an hour you see the dream of Rudolph Diesel come true.

Toward the end of the nineteenth century Diesel dreamed of an internal-combustion engine that would operate on cheaper fuel than gasoline. After a long train of difficulties, he gave to the world the engine that bears his name.

This engine, as shown on the opposite page, is similar to the gasoline engine, but it has neither carburetor nor spark plugs. Air is brought into the cylinders and compressed about twice as much as the vapor in the cylinders of a gasoline engine. This pressure heats the air to about 600° C. Fuel oil is sprayed into the cylinders by a powerful pump while the hot air is under compression, and the temperature is high enough to explode the fuel without the help of spark plugs. The strokes of the piston are then almost exactly like those of the gasoline engine.

Diesel engines are rapidly gaining in popularity. Not only trains, but trucks, tractors, and power plants, are using them in ever-increasing numbers. They are among the most efficient means as yet invented for turning the energy of heat into the energy of motion.

Importance of Heat. The engines which we have studied in this chapter are the very foundations of our machine civilization. A list of the tasks they are made to perform would demonstrate the tremendous importance of the energy of heat in the modern world. In studying the way these engines turn heat energy into mechanical energy we have had space only to suggest the tasks which this mechanical energy performs. But as we go deeper into this book we shall learn more and more about this phase of our subject.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Sunshine and heat are the same thing.
2. The direct rays of the sun are one of the most useful sources of energy for performing work.
3. The solar cooker is the best heating device in the world because the fuel is free.
4. When a material unites slowly with oxygen, as when iron rusts, we say that it undergoes combustion.
5. A strange thing about heat rays is that they give up their heat when they strike even so thin a material as air.
6. Conduction of heat may be demonstrated by dropping a small piece of tissue paper over a hot stove.
7. Woolen suits are good insulators because they keep cold air away from our bodies.
8. A fireplace heats a room chiefly by convection.

9. Hot-air furnaces are dangerous because hot air rises directly from the burning fuel and may carry poisonous gases.

10. Hot-water heating systems operate largely on the principle of conduction because convection is impossible in a liquid.

11. Steam heat is the cheapest and most even heat in the world.

12. A steam engine is called an internal-combustion engine because steam is developed inside a tightly closed boiler.

13. A heavy flywheel is needed to keep a steam engine from blowing up.

14. Steam turbines are cheaper to use than steam engines because they can operate on a lower grade of fuel.

15. The gasoline engine is called a four-cycle engine because it has four cylinders.

16. Diesel engines are better than gasoline engines for airplanes because they do not have to carry such heavy quantities of fuel.

Questions for Discussion

1. What type of heating plant do you think would be best for a small cabin in the woods? for a six-room house? for an apartment building? Why?

2. Why do you suppose a steam locomotive puffs?

3. At one time some automobiles were run with steam engines. Do you think there were any advantages in this? What were some of the disadvantages?

4. Why do the new streamline trains use Diesel engines rather than gasoline engines?

Things to Do

1. Keep a scrapbook on interesting uses for the engines described in this chapter. The newspapers frequently carry illustrated items about progress both in the construction of these engines and in their use in the workaday world.

2. Study the use of steam engines, steam turbines, gasoline engines, and Diesel engines. Read up on each type in the library and see how many different uses you can find for each type.

3. Visit a garage and see if you can study a gasoline engine that has been opened for cleaning. Try to identify the important parts. If the mechanic is in a good mood, he might be willing to explain things that you cannot puzzle out for yourself.

4. Read in an encyclopedia about the interesting life of Rudolph Diesel and how he invented the Diesel engine.

CHAPTER TEN

How Do We Use Light?

THE NATURE OF LIGHT

Light, the Sister of Heat. In the last chapter we began our studies with mention of the radiant energy of the sun. We learned that part of this energy when it reaches the earth is turned into heat and that heat can be put to work. Along with the heat rays there are other kinds of rays which the sun gives off, the most important of which are rays of light. Light, like heat, serves many useful purposes, as we shall now see.

Scientists are not sure just what light rays are. Many scientists believe that they and all other kinds of radiant energy reach the earth as waves, somewhat in the manner of the waves of water that strike a beach. Though they do not know exactly what light is, scientists know much about what light does. They know, among other things, that light, like heat, is a form of energy because it makes things move their position and change their form.

White Light. As we look at a beam of sunlight it appears to be white. A simple experiment, however, will show you that white sunlight is really made up of a combination of several colors.

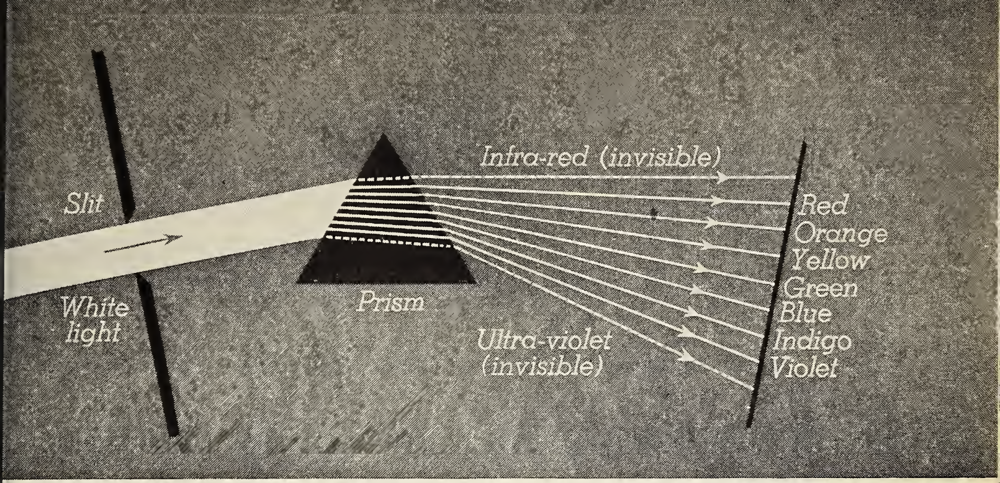
Exercise. How to break up sunlight into its various colors: Get a glass prism and set it up as shown on page 281. Darken the room excepting for a beam of sunlight that is allowed to enter between the shade and a window sill. Set up the prism so that the light passes through the prism and strikes a piece of white cardboard. Are the colors arranged as in the illustration?

A prism such as you used in the above experiment is an essential part of a *spectroscope*, which means "a watcher of vision." The bands of color that appeared on the white cardboard are called the *spectrum*. When white light is broken up by the prism, it is always separated into the colors that appeared in your experiment. Red is always at one end of the spectrum and violet at the other end. Between these two are always orange, yellow, green, blue, and indigo, in that order. All the colors blend gently into one another.

What Causes the Spectrum. The visible colors of the spectrum are due to the fact that white light is a mixture of light waves of different lengths. Just as the crests of some ocean waves are close together and the crests of others are farther apart, light waves are thought to vary in length. Though all light waves are extremely short (several millions to the inch), the wave length of red light is about twice as long as the wave length of the violet light at the opposite end of the spectrum.

Scientists believe that though light waves vary in length, they all travel through space at the same speed. And such a speed! A ray of light can circle the earth five times during the beat of your pulse; or, more exactly, 186,264 miles per second. This is so fast that the human eye cannot detect the movement.

When sunlight strikes materials at the surface of the earth, its speed is somewhat slowed down. Even the air slows down the speed a little, and solid materials slow it down a great deal more. When waves of sunlight pass through a glass prism, the shorter waves are slowed down



With the help of a glass prism white sunlight can be broken into seven colors

more than the longer ones. This separates the waves according to length and allows them to show forth in their true colors.

Why Light is Bent When It Passes through a Prism. When a beam of sunlight enters a glass prism, all the rays are traveling along straight parallel lines, as shown above. After they leave the prism they are still traveling in straight lines, but all of them have been turned from the direction along which they were traveling before they entered the prism. Let us see what causes this change.

Notice that the beam of light strikes the prism at a sharp angle. The result of this is that the light on one side of the beam enters the prism before the light on the other side. The prism slows down the speed of all the light, but that which enters first is slowed down first. This turns the beam away from the direction along which it entered the prism. Because the longest (red) waves move through glass the fastest, their direction is changed the least. The shortest (violet) waves move through glass the slowest, and therefore their direction is changed the most. The waves of other lengths are bent in the same way, according to their speed.

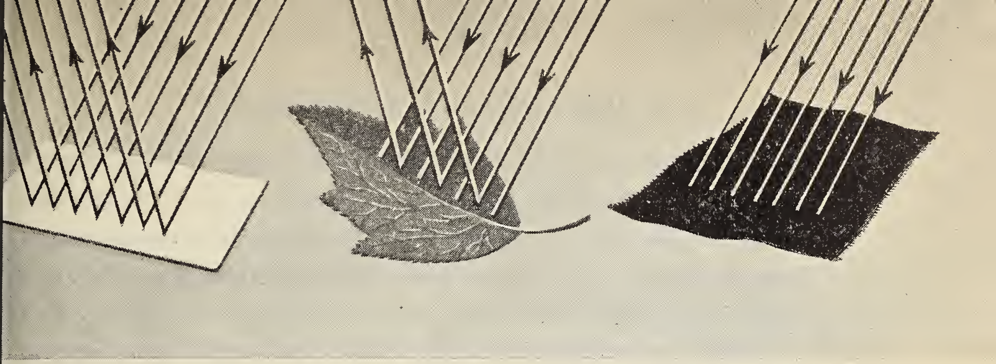
Exercise. How does the rainbow get its colors? Look up an explanation of this interesting sight and report on it to your class. Why are the colors of the rainbow arranged in the same order as the colored bands of the spectrum?

How Materials of Different Colors Absorb and Reflect Light. What happens to the rays of light when they strike differently colored materials? You can find out by letting the colors of the spectrum strike pieces of differently colored paper. Let us say that you exchange the white cardboard, which you used in your experiment with the prism, for a piece of brilliant red paper. If the paper is pure red, no color but red will show up on it.

In the same way, if you use a bright-blue paper, no

The color of a dress depends on what wave length or wave lengths of light the dye in the cloth refle

Lambert



white paper on the left completely reflects light rays from the sun. The green in the middle reflects the rays that give the sensation of green and absorbs all other rays. The black cloth at the right absorbs all rays from the sun

color but blue will be clearly visible. The same is true of orange, yellow, green, indigo, and violet papers. In other words, the color that appears clearest on each of the colored papers is the color of the paper itself. How can we explain these observations?

The explanation is that a colored object upon which light shines soaks up, or *absorbs*, all the light rays except those of a single wave length. The light which it does not absorb bounces off the object much as a tennis ball bounces off a racket. It is the waves that bounce off the object, or are *reflected*, that we see. It is these waves that give us the impression of the color of the object.

A blue dress, for example, appears blue because the dye in the dress reflects only the wave length of light that gives us the sensation of blue. Similarly, a red dress reflects only the wave length that gives us the sensation of red. A white dress reflects all wave lengths and gives us the sensation of white, which, as we have seen, is a combination of all colors. A black dress, on the other hand, does not reflect any light at all. It gives us the sensation of black, which is the absence of all colors (see opposite and above).

Invisible Rays. As the diagram on page 281 shows, certain waves of sunlight are longer than the red rays, and certain others are shorter than the violet. In one sense these waves cannot be called light rays at all, because the human eye does not see them. On the other hand, they are always present in sunlight and are as much a part of it as the rays which the human eye does see.

The rays which are longer than those that give us the sensation of red are known as *infrared rays*. It has been found that if a camera is fitted with a filter that allows only infrared rays to pass through, clear photographs may be secured of objects at a great distance. Such photographs may be taken in darkness if infrared rays are present.

The picture at the left below was taken with a regular camera and film. The one at the right was taken with a special filter and a film which was sensitive to infrared rays. One reason for the differences between them is that infrared rays penetrate haze better than ordinary light does.

The rays of sunlight which are shorter than those that give us the sensation of violet are known as *ultraviolet rays*. These are the rays that produce sunburn. They are also

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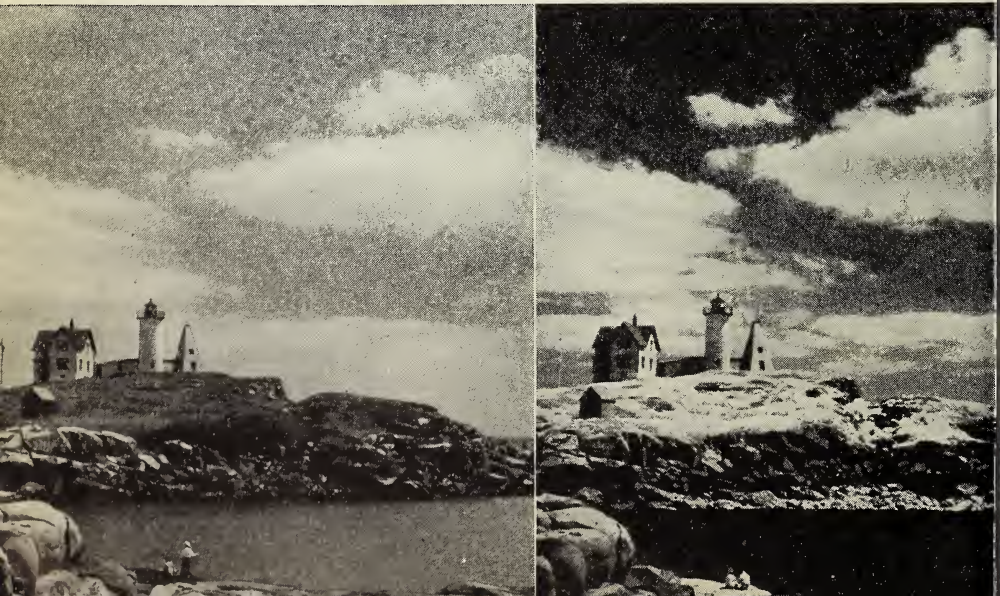
The photograph at the left was taken with ordinary sunlight; the one at the ri
with the ultraviolet rays alone. What is the chief difference between the two pictu

Photographs taken on Agfa Film



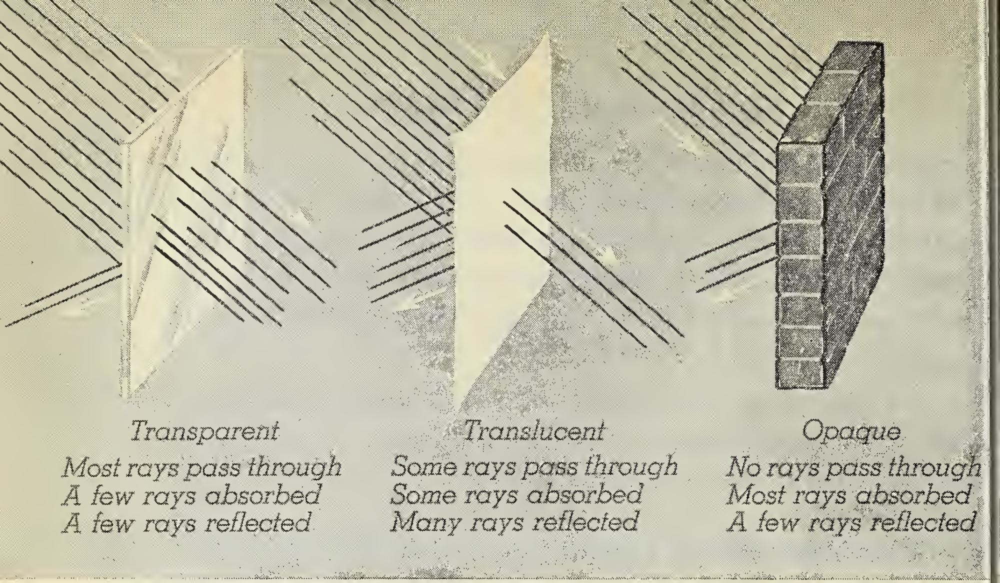
responsible for most of the changes that take place when we expose a photographic film to the light. All living things need these rays to help them live healthy lives. Since the ultraviolet waves cannot pass through ordinary window glass, we should try to spend a part of every day outdoors.

X rays, radio, and wireless waves must also be counted among the invisible forms of radiant energy. About these we shall learn more in a later chapter.

What Makes Objects Visible. Just how do the rays which we call visible light make objects visible to our eyes? Let us say that you are doing your homework when suddenly the electric lights go out. Your books and papers suddenly disappear from view. You know that they are exactly where they were before the lights went out and you can imagine what they look like. But you cannot see them.

Then just as suddenly the lights flash on again. Everything in the room that can be touched by the rays from these lights comes into view. Things so touched, in other words, become *luminous*, which means that they are capable of sending out light rays to your eyes. The electric lights in the room are luminous in themselves. The objects on which their rays fall are luminous because they reflect some of these rays to our eyes. But whether objects are luminous in themselves or luminous by reflection, *you see what you see only because light rays travel from the object to your eyes.*

Exercise. We have discussed the sun and electric lights as objects which are luminous in themselves. Can you name any other objects or materials which are luminous in this fashion or which can be made so?



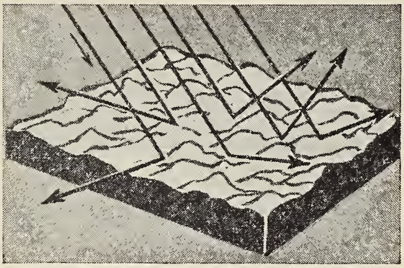
These drawings explain what happens to light rays when they strike different types of mate

What Happens to Light When it Strikes an Object. Let us go a bit farther into the matter of what happens to the light that falls upon the objects around us. What happens, for example, to light that strikes a pane of clear glass? What happens to light that strikes a piece of white tissue paper? What happens to light that strikes a brick wall?

Most of the light that strikes the pane of clear glass passes through it, though a little is absorbed and a little is reflected away. Such substances as clear glass, water, air, and diamonds, which allow much light to pass through them, are said to be *transparent.*

A piece of white tissue paper, on the other hand, puts up more of a barrier to the passage of light. More light is absorbed and much more reflected than in the case of clear glass. Some light, however, does pass through, as you may see if you hold the paper up to the light. But not enough gets through to enable you to see objects on the other side very clearly. Materials which act in this fashion are said to be *translucent.*

Exercise. How many translucent materials can you name?



Diffused light is produced by reflection from uneven surfaces

Finally, a brick wall absorbs most of the light that strikes it, reflecting a little but allowing none to pass through. Materials such as this, which allow no light to pass through them, are said to be opaque. The illustration on the opposite page will help you to remember these three different things that may happen to light when it strikes the objects around us.

Reflection and Refraction of Light. We have seen that nearly all surfaces are able to reflect some light. Light-colored polished surfaces, like mirrors, reflect a great deal. Dark, rough surfaces, like a brick wall, reflect only a little. Nearly all the light that comes to our eyes is reflected to them by rough surfaces. This light bounces off these irregular surfaces in an irregular manner, as the diagram above indicates. Such light is said to be *diffused*, or scattered. It accounts for the redness of the sunset, the blueness of the sky, the haziness of the atmosphere of a smoke-filled city, and many other aspects of the world in which we live.

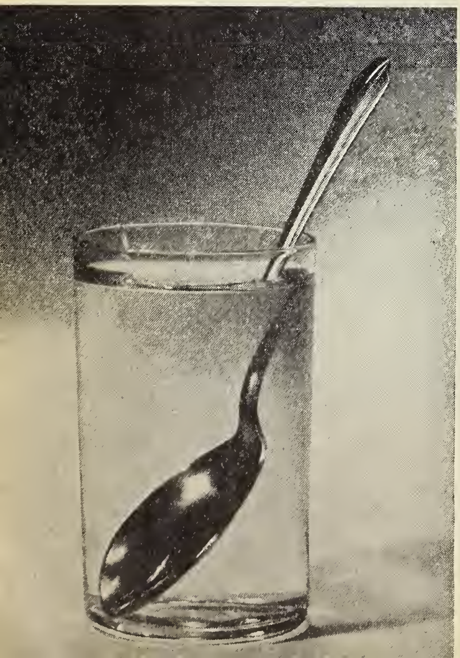
Exercise. Look up in a physics textbook the cause of twilight and report on your findings to your class.

Have you ever noticed that when a spoon is placed in a glassful of water it seems to be bent at the surface of the water (see page 288)? This strange effect is caused by the fact that the water changes the direction of the light rays that come to your eye from the spoon. This bending of light rays is known as *refraction*. It is caused in this case by the fact that the light rays are somewhat slowed down when they move from air to water. Refraction always occurs when light passes from one transparent material (at one rate of speed) into a different transparent material (at a different rate of speed).

Exercise. Place a penny on the bottom of a deep pan, such as the pans which your mother may use for baking. Place yourself so that you can just see the edge of the penny when you look over the edge of the pan. Then have a companion pour water into the pan. What happens to your view of the penny? Why?

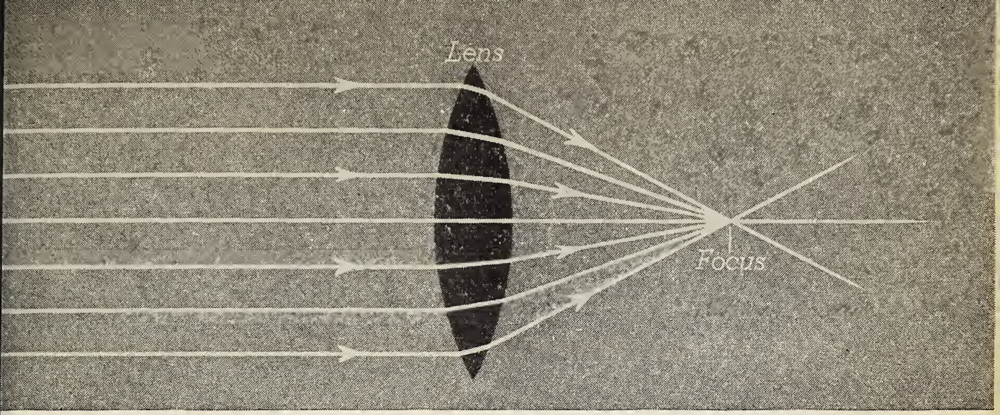
Many of our modern uses of light depend upon the properties of reflection and refraction. In the following section we shall study some of these uses.

The bending, or refraction, of light rays makes this spoon appear to be broken



INSTRUMENTS THAT MAKE USE OF LIGHT

What a Lens Does to Light. The lens is a common instrument for the use of light. If you have ever used a magnifying glass, a camera, a microscope, a telescope, or field glasses, you know something about lenses. Whenever you look at an object you use the lenses of your eyes. If you wear glasses, you use glass lenses to help the lenses in your eyes to perform their jobs.



A convex lens brings light rays to a focus

Let us see if we can learn what a lens does to light by studying the lens of a simple magnifying glass. You will notice that the lens in this instrument is merely a curved piece of clear glass. Both surfaces are bulged outward in the center as shown above. A lens such as this, which is thicker in the center than at the edges, is called a *convex lens*.

You have probably used a convex lens to catch the rays of the sun and to flash them around a room. Perhaps you have used it to bring heat waves to a point. In such a case the "magnifying" glass becomes a "burning" glass, because the little point of bright light contains heat rays which can burn holes in paper. In either case, you used the convex lens to bring the rays of the sun together in what is called a *focus*. The ability to do this to light is the chief characteristic of convex lenses.

In your study of a prism you learned that light is bent from a straight line as it passes through glass. In a prism the light is turned toward the thick part of the glass. The same thing is true of a convex lens, as the diagram above shows. The thickest part of the glass is in the center, so that all the rays that fall on the glass are turned toward the center. Since this is the case, you can see why the parallel rays that enter the lens on one side come to a point, or focus, after passing through the other side.

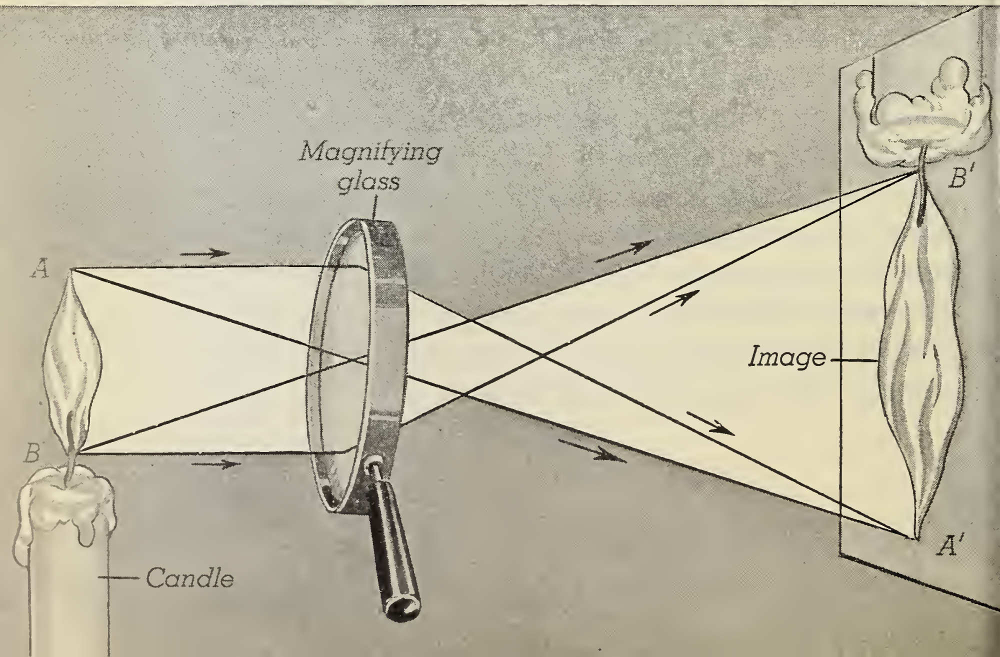
Why a Convex Lens Inverts an Image. A simple experiment will show you another interesting fact about convex lenses.

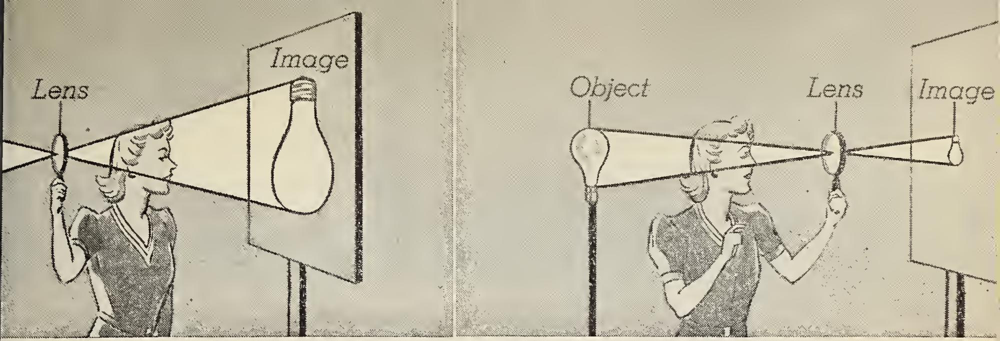
Exercise. Arrange a lighted candle, magnifying glass, and a piece of white cardboard in a dark room, as shown below. Move the lens until the image of the flame on the cardboard is sharp. What is the most striking difference between the image of the flame and the flame itself?

In performing the above experiment you may be surprised to see that the image of the flame is upside down, or *inverted*. If you study the diagram below carefully, you will discover why this is so.

Notice that AB represents the position of the flame, and $A'B'$ the position of the image. The lines leading from A through the lens to A' show what happens to light that enters the lens from the tip of the flame. Notice that though these rays strike the lens at different angles and in different places, the lens is curved in such a way as to bend, or refract, the rays so that they will come together in a

This diagram shows how a convex lens inverts an image





The position of a lens affects the position and size of the image

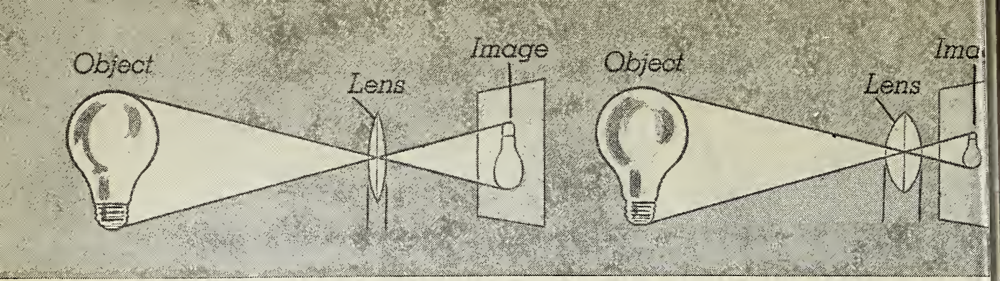
focus at A'. Similarly, all other rays that enter the lens from A are refracted so that they will come together at A'. An image of the point A therefore forms at the point A'.

In the very same way, the lines leading from B through the lens to B' are bent and focused. Similarly, the rays from all points between A and B take up their proper places in the image between A' and B'. Do you see then how the image is formed and why it is upside down?

The Size of the Image. Images of objects seen through convex lenses may be either larger or smaller than the objects, as a simple experiment will prove.

Exercise. Arrange an electric-light bulb, magnifying glass, and piece of white cardboard as you did the equipment in the last experiment, but place the magnifying glass exactly one foot in front of the bulb before moving the cardboard into a position where a clear image of the bulb appears. Is the image larger or smaller than the bulb? Now repeat the experiment, but place the glass two feet from the bulb. What does this do to the size of the image?

This simple experiment illustrates a fact which holds within certain limits for all convex lenses. The closer an object is to a lens, the farther away from the lens and the larger will be the image. The farther an object is from a



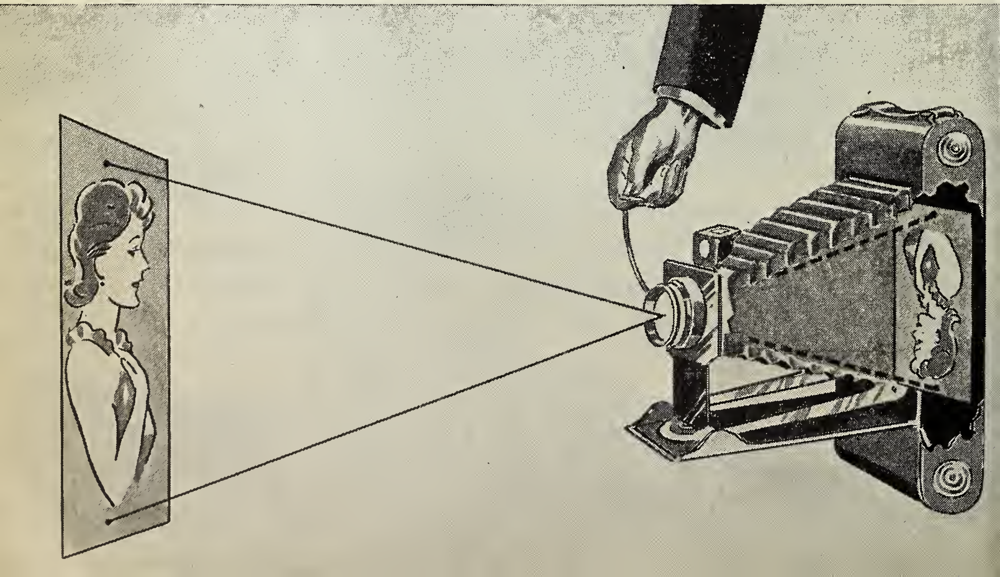
The thickness of a lens affects the position and size of the image

lens, the closer to the lens and the smaller will be the image. The diagram on page 291 will illustrate this point.

The thickness of a lens also affects the position and size of an image. A thick lens bends the light rays more than does a thin lens, with the result that the image is closer to the lens and smaller than in the case of a thin lens (see above).

How a Camera Lens Works. The camera is one of the simplest instruments that make use of lenses. As the illustration below shows, the light from the object to be photographed enters the lens when you "snap" the picture and is refracted upon the sensitive film behind. The image of the object is inverted for reasons that we discussed above. By moving the position of the lens, images of objects at various distances can be brought into focus on the film.

In a camera a lens is used to focus the image of an object on a sensitive film



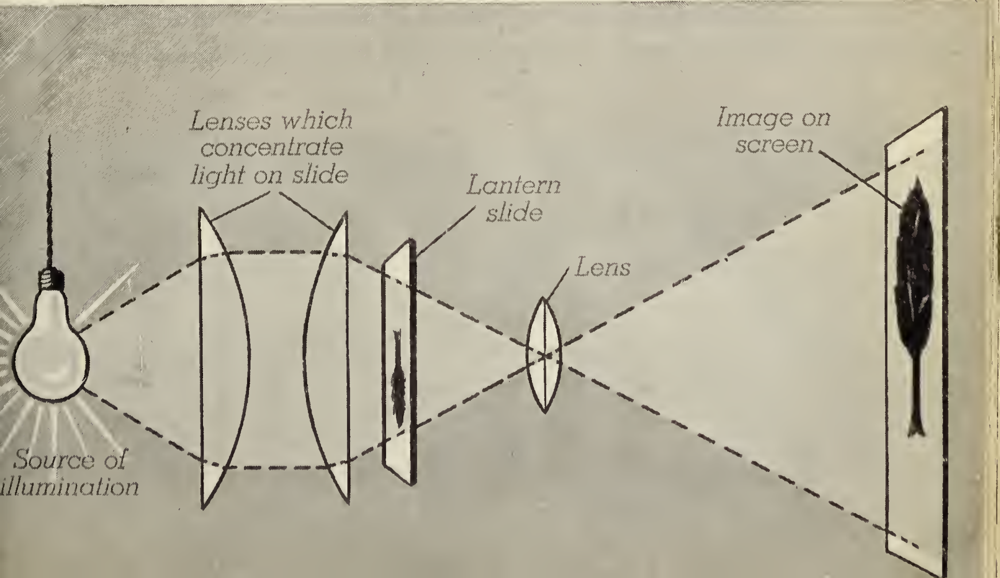
Exercise. If you wanted to take an enlarged picture of the head of the girl shown on the opposite page, what should you do? Why?

Instruments That Use More than One Lens. Below is a diagram of the working parts of an ordinary picture projector ("magic lantern") which is used to throw the enlarged images of pictures on a screen. Notice that the rays from a powerful electric light first go through two lenses which are flat on one side and curved on the other. These lenses act merely to catch the light and to concentrate it on the lantern slide, as the diagram shows.

The light, after passing through the glass slide which contains the picture to be thrown on the screen, next enters an ordinary convex lens. Because this lens is near the slide and far from the screen, the image appears on the screen very much enlarged. Because this lens inverts the image, the picture on the slide must be inserted upside down so that the image on the screen will be right side up.

Microscopes, field glasses, and telescopes also use combinations of lenses to enlarge the objects which are viewed through them. These instruments are much more compli-

The picture projector uses a combination of lenses



cated than the ones we have described. If, later on, you take a course in physics, you will learn how they operate.

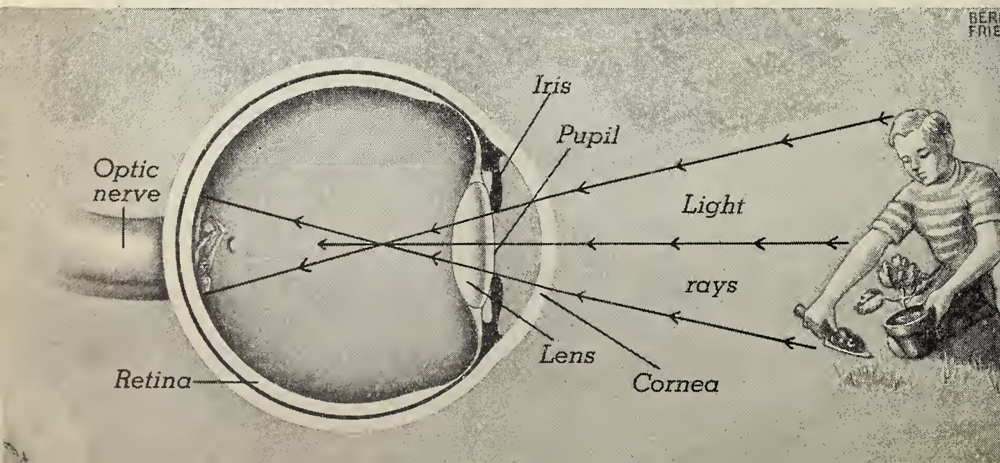
The Human Eye. The most wonderful instrument for the use of light is the human eye. It is something like a camera, except that it focuses itself and takes all its pictures on one film. The diagram below shows the construction of the eye.

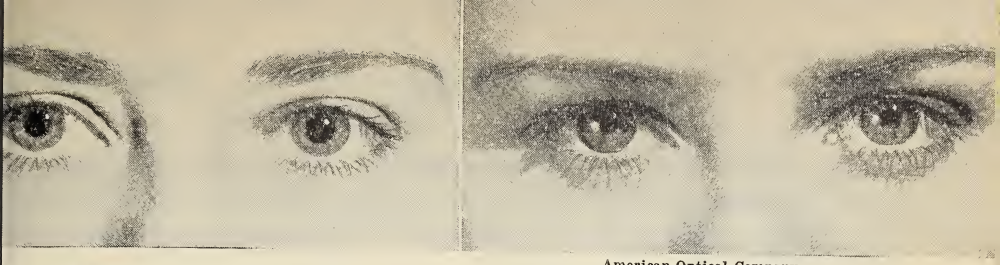
Notice that the front of the eyeball consists of a tough membrane, the *cornea*. Behind this is an opening called the *pupil*, whose size is made larger or smaller by movement of the *iris* which surrounds it. In this way the amount of light that enters the eye is controlled, as the photographs on the opposite page show. Behind the iris is the *lens*, which focuses the light rays near the back of the eyeball on a film that is known as the *retina*.

We have already seen in the illustration on page 291 that objects at different distances from a lens make images that are also at different distances from the lens. This means that *objects at different distances from a lens cannot be brought into focus at the same time.* The eye is no exception to this rule, as a simple observation will prove.

Exercise. Hold this book in such a way that the print is clear and easy to read. While looking at the print, are objects in the background clear or blurred? Now shift your gaze to some object in the background until it be-

The human eye is a superior sort of camera





American Optical Company

pupil of the eye can enlarge
to let in more light (left) and contract to let in less light (right)

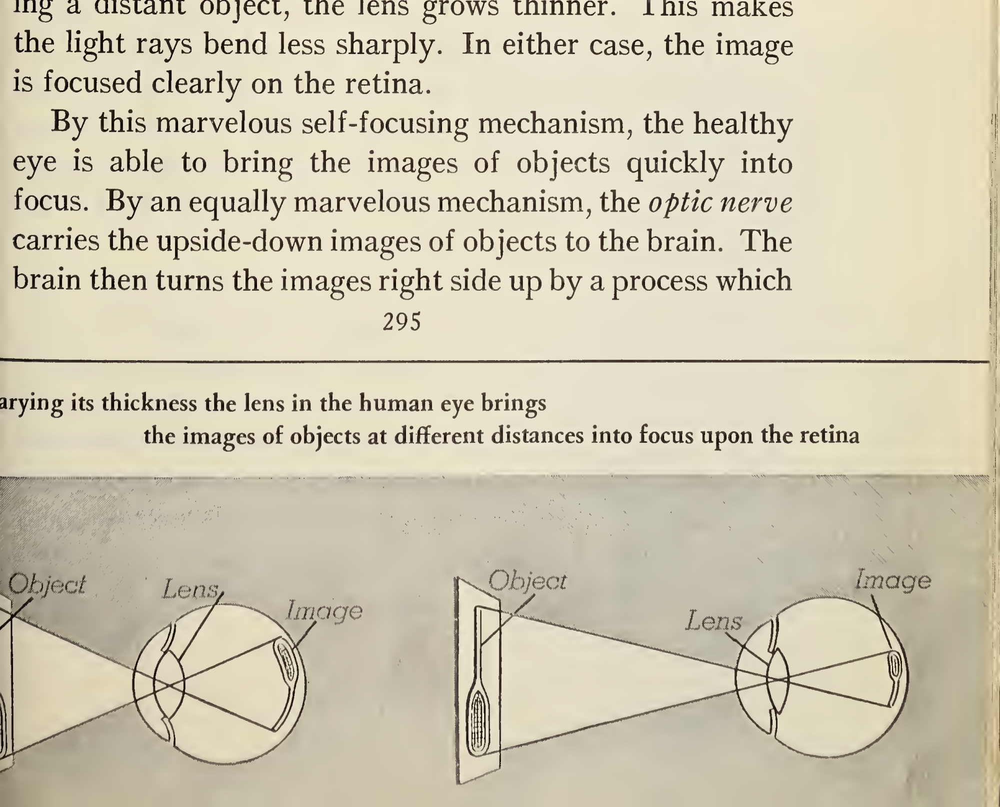
comes clear. What happens to the appearance of the print when you do this? Can your eyes focus clearly on two objects at different distances at the same time?

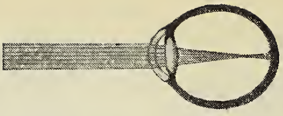
How can your eyes focus first on a near and then on a far object? They cannot do it by changing the distance between the lens and the retina in the way that the distance between the lens and the film of a camera is changed. They do it, on the contrary, by changing their thickness.

When viewing a close object, the lens of the eye grows thicker in the center. This makes the light rays that enter the lens bend more sharply, as shown below. When viewing a distant object, the lens grows thinner. This makes the light rays bend less sharply. In either case, the image is focused clearly on the retina.

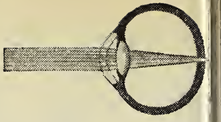
By this marvelous self-focusing mechanism, the healthy eye is able to bring the images of objects quickly into focus. By an equally marvelous mechanism, the *optic nerve* carries the upside-down images of objects to the brain. The brain then turns the images right side up by a process which

arying its thickness the lens in the human eye brings
the images of objects at different distances into focus upon the retina

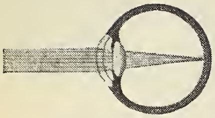




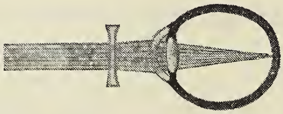
Nearsighted eye



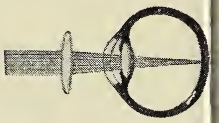
Farsighted eye



Normal eye



The focus of a nearsighted eye corrected by a concave glass lens



The focus of a farsighted eye corrected by a convex glass lens

Eastman Kodak Company

is not very well understood and makes it possible for us to see things as they really are.

Defective Vision and How to Correct It. When the human eye is working normally, images of objects are brought into sharp focus on the retina, as shown in the drawing at the left above. In some cases, not uncommon among growing children, the eyeball becomes too long or the lens too round to work absolutely correctly. Light rays are focused a little in front of the retina, as shown in the upper middle drawing above, and the images of objects are blurred. This condition is known as *nearsightedness.*

Fortunately, nearsightedness is easily corrected by the use of glass lenses which are slightly basin-shaped, or *concave.* Unlike convex lenses, which bring light rays together, concave lenses spread the rays apart. By wearing properly fitted concave lenses over the eyes, as shown in the lower middle drawing above, the light rays are spread enough so that they will focus on the retina. By so doing they help nearsighted eyes to produce clear images.

Farsightedness is the opposite of nearsightedness and is not uncommon in older people. The lenses of the eyes in farsighted people have lost some of their ability to change their form. As a result, they cannot become convex enough to focus exactly on the retina. They focus instead a little behind the retina, which blurs the image, as shown in the upper right drawing on the opposite page. By wearing convex glasses, the light rays can be bent so that they will focus properly (as shown in the drawing at the lower right).

Several other types of defective vision may be corrected by the use of properly fitted glass lenses. Indeed, there is no department of science that has done more good for more people than the science of the control of light.

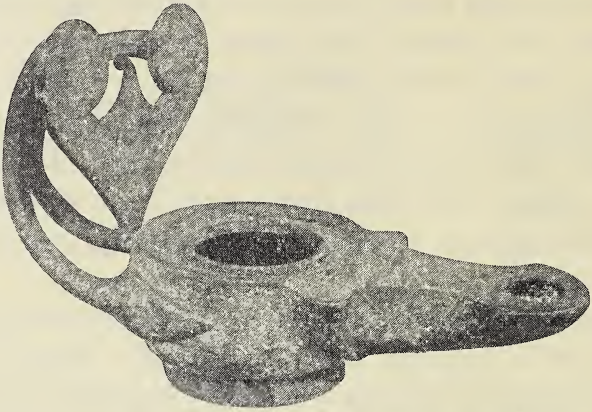
OUR USE OF ARTIFICIAL LIGHT

The Need for Artificial Light. When the lights in our homes go out for only a few moments, we realize how much we have come to depend on artificial light. Some animals have large eyes for gathering in the weak light from the stars and the moon, but our eyes are not built for this purpose. Because man has always been an energetic creature, he has not been content to go to sleep when darkness falls. Part of the story of civilization is the story of the search for ways of turning night into day.

The tarsier, who transacts his business at night, has large eyes which gather in light from the stars and the moon

A. M. N. H.

Source of Artificial Light. We have already seen the close relationship between light and heat. When men first learned how to make fuels yield heat, they also learned how to produce artificial light. Since then the development of heating and lighting have gone on together. Today we have such fine artificial lighting that for nearly all tasks we can see just as well by night as by day.



The Metropolitan Museum of Art

For centuries such lamps as this were the chief source of artificial light

We must remember in this connection that the energy which makes artificial light possible is the same energy that makes natural light possible. Whether we use wood, oil, coal, or water power to light up our buildings at night, we use energy that originally came from the sun.

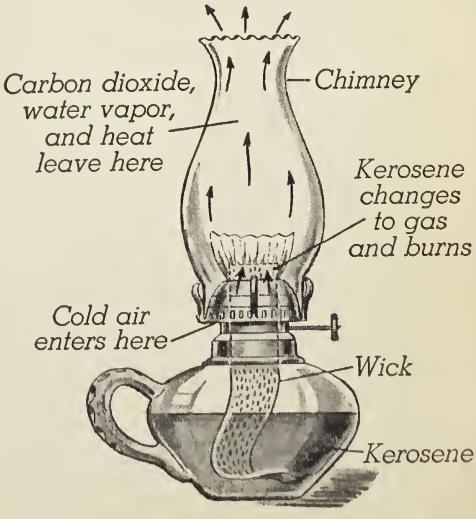
Early History of Lighting. The campfire was probably the first lamp, as it was probably the first heater. Just how lighting progressed from the campfire to the lamp which is pictured above, nobody can say. Perhaps primitive men discovered that wood with pitch burned better and brighter than wood without it. Perhaps they observed that fat meat dripped oil that flared up when it struck the hot embers of the campfire. At any rate, ancient lamps filled with vegetable or animal oil were in use long before the birth of Christ and for many years were the chief means of producing artificial light.

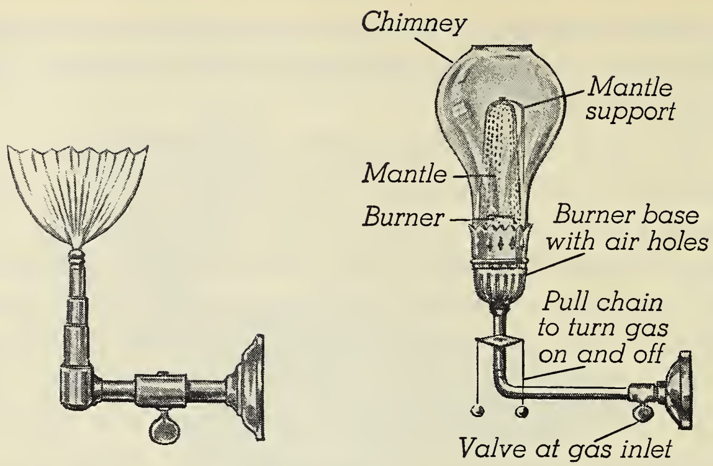
The tallow candle was a great improvement over the primitive oil lamp because it smelled and smoked much less, and also because it gave a great deal more light. It was not invented, however, until well into the Middle Ages. Not until after Columbus discovered America were glass chimneys used to control the flicker and thus to change candles into reliable lamps and lanterns. Not until the close of the eighteenth century was the first real triumph of artificial illumination, the kerosene lamp, achieved.

The Kerosene Lamp. The kerosene lamp (which operated chiefly on coal oil before the refining of petroleum was perfected) was a logical development of the primitive oil lamps of the ancients. The primitive lamp was merely a dish filled with oil, with a rag for a wick. The kerosene lamp improved on this crude arrangement by adding a glass chimney, a closely fitted cotton wick, and air vents at the base of the flame to assist the burning (see below).

Notice that the oil moves up the wick and changes to gas at the upper end. When the lamp is lighted, this gas is burned. Convection currents carry carbon dioxide, water vapor, and heat out the chimney. The lamp burns steadily because a steady stream of oil moves up the wick and a steady stream of air moves into the air vents and out through the chimney.

Though simple in principle and construction, the kerosene lamp was not invented until the close of the eighteenth century


Carbon dioxide, water vapor, and heat leave here
Chimney
Kerosene changes to gas and burns
Cold air enters here
Wick
Kerosene



The fishtail gas burner (left) gave more light than a kerosene lamp. The Welsbach burner (right) was brilliant but delicate

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Exercise. Study a kerosene lamp until you understand how it works. Why does it smoke when you turn up the wick too far?

The Gas Light. Though kerosene lamps are still in use, they were rather generally replaced by the gas lights illustrated above. Your parents may possibly remember and your grandparents will certainly remember when nearly all homes and business buildings were lighted in this fashion. Today we hear jokes about the "Gaslight Era," but gas light was no joke for the people who lived in that era. It was a great achievement in artificial lighting.

In Chapter Seven we learned how artificial gas is made from coal. During the late nineteenth and early twentieth centuries most of this kind of gas was used for lighting. It was piped into buildings and burned in one or the other of the burners shown in the illustration. The *fishtail burner*, though crude, gave considerably more light than an ordinary kerosene lamp.

The *Welsbach burner* produced an excellent light, even by modern standards. In it a mantle spun from the mineral thorium was made to glow brightly in the intense heat of a gas flame. The heat of this burner burned up all the elements of the gas that might otherwise have produced soot and unpleasant odors. Welsbach mantles gave out a steady and clean light, but the mantles were delicate and had to be frequently replaced.

Exercise. Welsbach mantles are still used in gasoline and some kerosene lamps. Get one of these lamps and study its operation.

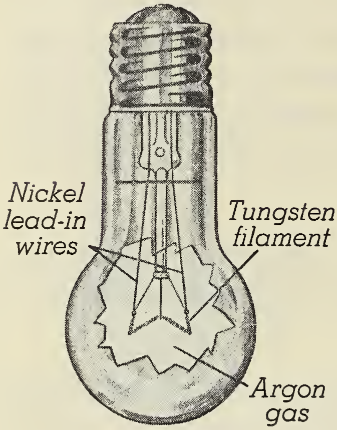
The Electric Lamp. When Edison invented the electric lamp, in 1879, he signed the death sentence of the gas lamp. Though gas lamps competed with electric lamps during the early years when electric lamps were still crude, costly, and unreliable, they have long since given up the fight. The electric lamp of today is easily the best kind of artificial illumination ever invented.

The modern electric lamp diagramed on page 302 consists of a small wire (filament) made of the metal tungsten, which is sealed in a glass bulb that has been filled with the inactive gas argon. When an electric current is passed through the lamp, the filament heats up to a very

Gas lights helped to make the "gay nineties" gay

Keystone-Underwood

high temperature. Since there is no oxygen in the bulb to combine with it, the filament cannot burn. Instead, it glows with the bright, white light that we all know so well.



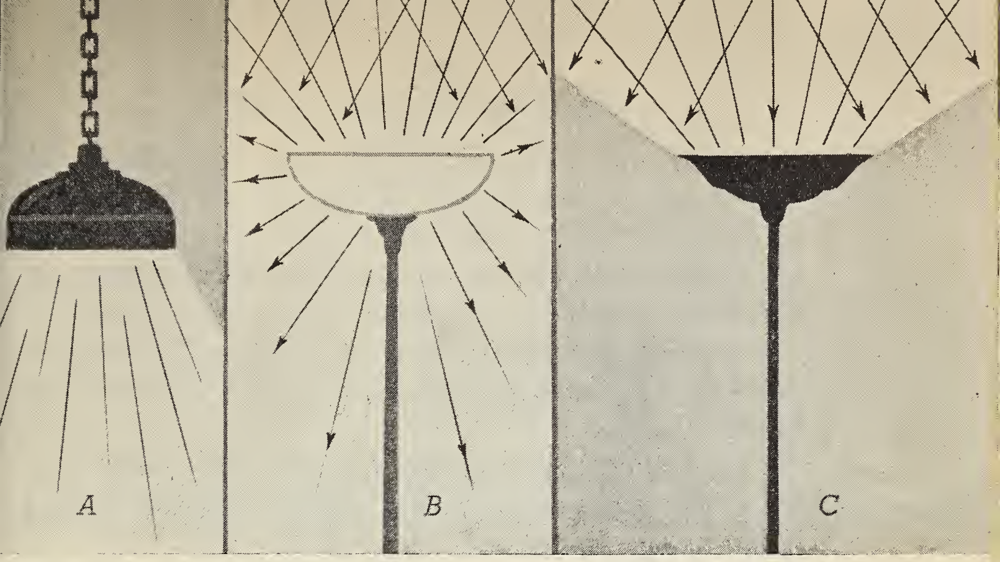
This is one type of modern electric bulb

Exercise. There are types of electric lamps in use today which are somewhat different from the type described above. See if you can find out how these lamps are constructed. The electric-light company in your neighborhood can probably help you in finding this information.

Lighting in the Home. Just as the types of artificial lights have improved with time, so have the methods of using artificial light. By the proper use of lighting, buildings can be made as bright by night as by day, without any great strain on the eyes.

Light fixtures are of three kinds, as shown on the opposite page. *Direct lighting* occurs when the light shines directly on a reflecting surface, as in the case of an ordinary desk or table lamp. Direct lighting, the cheapest of the three kinds of lighting, is also the least desirable because it produces glare which is harmful to the eyes.

In *semidirect lighting* the lamp is encased in a translucent glass shade which allows some of the light to radiate out at the bottom and some to strike the ceiling, from which it is reflected into the room. In *indirect lighting* the lamp is placed in an opaque bowl which throws all the light against the ceiling. Both these types give a soft and evenly



Modern artificial lighting is direct (A), semidirect (B), or indirect (C)

distributed diffused light which is easy on the eyes. Complete indirect lighting is somewhat better for the eyes than semidirect lighting, but also more expensive. For most purposes semidirect lighting is the more desirable.

Exercise. Examine the artificial lighting in your home. Are there any places that are not lighted enough? Are there any places with too much glare? Make a study of how you could improve conditions by changes in either the arrangement or the style of the lights.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. White and black are combinations of all the colors of the spectrum.

2. When sunlight passes through a prism, the red rays are slowed down more than the violet ones.

3. A piece of red paper looks red because it absorbs only the red rays of the sunlight.

4. Ultraviolet and infrared rays are, respectively, the longest and the shortest rays of light that can be detected by the eye.

5. We are able to see because light reflected from our eyes strikes the objects around us.

6. Transparent and translucent objects are the same because in both cases light can pass through from one side to the other.

7. Diffused light is another name for reflected light.

8. Refraction occurs when light is reflected from a bright opaque surface such as a mirror.

9. A convex lens is one that is thicker at the edges than at the center.

10. The closer an object is to a lens, the smaller will be the image.

11. The human eye is more efficient than a camera because it can bring objects at different distances into focus at the same time.

12. The retina is that part of the eye which turns images right side up.

13. The tallow candle was in use long before the birth of Christ and was the chief source of artificial light until the late Middle Ages.

14. Indirect lighting is not only the cheapest lighting, but it is also the easiest on the eyes.

Questions for Discussion

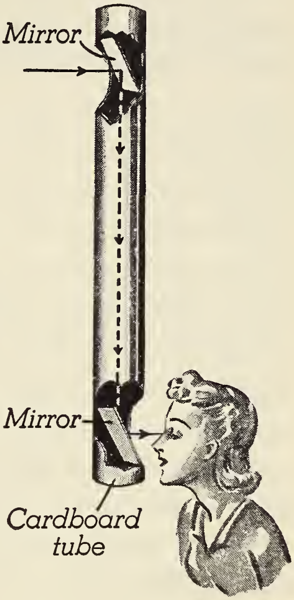
1. If it is true that a cat can see in the dark better than we can, what may be a possible explanation?

2. Is black a color? white? infrared? ultraviolet? Explain.

3. What is really meant when it is said that a camera is out of focus?

Things to Do

1. Make a camera obscura, commonly known as a "pinhole camera." There are various types of pinhole cameras, but the simplest can be made in a few minutes, as follows. Get a cardboard shoe box, cut the cardboard out of one end and replace it with a piece of thin white paper. Then punch a very small hole in the center of the opposite end of the box. If you look through the thin-paper end of the box at a well-lighted object, you will see an image of the object on the thin paper by means of the light that enters through the pinhole. By throwing a coat or dark cloth over your head so that no light can enter at the back of the camera, the image will be bright and clear.



Here is a pattern for a simple periscope

2. Perhaps you would like to make a periscope such as a submarine uses to sight objects at the surface of the sea when the submarine is under water. Get a cardboard tube such as is used for mailing calendars and other paper articles that must not be wrinkled. Cut holes near the ends of the tube and insert small mirrors, as shown above. The light that strikes the upper mirror is turned and reflected to the lower mirror, which turns it again and reflects it to your eye. With the help of this simple instrument you can see round the corners of buildings and over the tops of walls that are taller than you are.

3. Read Simonds's *Edison* or some other book in the library that tells the interesting story of the electric light. Make a report to your class on the invention and improvement of this type of artificial lighting.

4. If there is an airport in your neighborhood, see if you can find out how different kinds of artificial lights are used for lighting the field and for signaling the planes.

CHAPTER ELEVEN

How Do We Harness Electricity?

THE NATURE OF ELECTRICITY

The Importance of Electricity. Of all the forms of energy which we have harnessed to perform the tasks of the modern world, electricity is the most important. Our age is truly not only an age of iron but also an age of electricity. Everywhere we go we see electricity at work. We see it in our houses, lighting the lights, ringing the doorbells and telephones, toasting the bread, and cooling the refrigerators. Beyond our houses we see it moving streetcars, lifting elevators, and turning the wheels of countless industries.

Electric energy has become so highly important in our lives (1) because it is easy to produce and control, and (2) because it can easily be changed into other forms of energy, such as light, heat, and motion. But what is this giant that can do so many things?

How Electricity Got Its Name. Like the energy of heat and light, the energy of electricity is as mysterious as it is marvelous. We know it rather for what it does than for what it is. Though it has come into its own as a mighty servant of man only within the past fifty years, something of what electricity can do was known to the Greeks more than three hundred years before the birth of Christ.

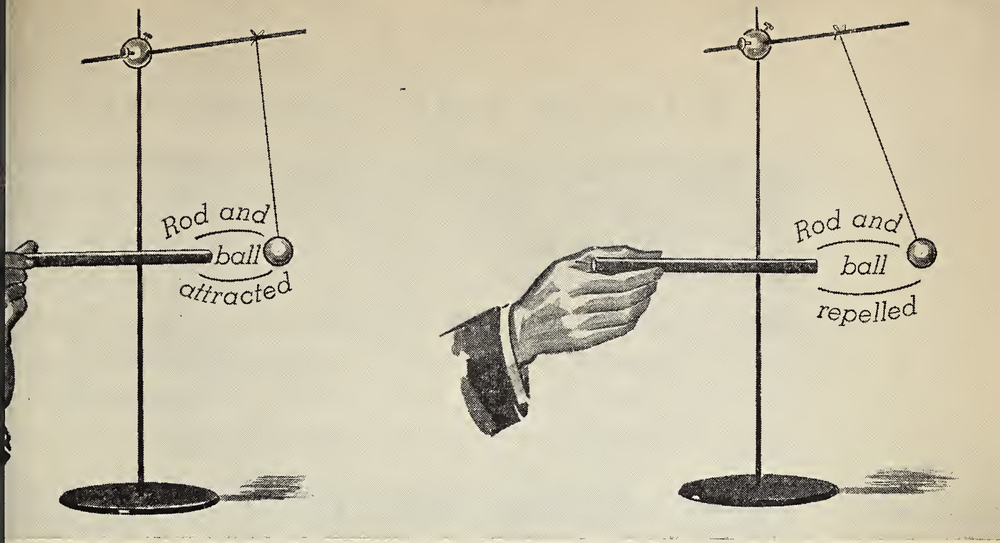
These early people knew, for example, that amber, a hardened gum which they used in making trinkets, would take on peculiar properties if rubbed with a piece of fur. They knew that this substance, which they called *elektron*, gained the ability when rubbed to pick up small pieces of paper or other very light objects. Today we know that many other materials gain the same ability when rubbed.

Exercise. Vigorously rub a rubber comb with a woolen cloth or the sleeve of your sweater, and then hold it near a small bit of paper. What happens?

The court physician during the reign of Queen Elizabeth observed the attraction which you demonstrated in the simple experiment above. He called it *electric*, after the Greek word for amber. So it was that the word "electricity" came to be used for the strange form of energy which nobody can really define but which anybody can produce merely by rubbing a piece of hard rubber with a woolen cloth.

The Law of Electric Charges. In America, Benjamin Franklin became interested in electricity. You have probably seen pictures of Franklin flying his famous kite during a thunderstorm. He had long been puzzled about lightning and finally decided to find out about it for himself. It is a wonder he wasn't killed, for his experiments with lightning were far more dangerous than he realized. Through his experiments, however, he proved that the streak of lightning and the spark that

This boy is testing the effect of electricity produced by rubbing a hard rubber comb with a woolen cloth



h ball is first attracted to, and then repelled by,
a hard rubber rod which has been rubbed with fur or wool

can be made to fly from a stick of rubbed amber are essentially the same. His experiments and those of many other investigators are the foundations upon which the present knowledge of electricity has been built.

The properties of electricity, as Franklin and other early investigators discovered them, can be demonstrated by a few simple experiments similar to the one that you have just performed with a rubber comb.

Exercises. Hang a dry pith ball (pith is the light substance you find in the hollow stems of plants) from a support by means of a silk thread. Vigorously rub a hard rubber rod with fur or wool and then bring it close to the ball, as shown above. Notice that the ball is first attracted to the rod. After the ball has touched the rod, move the rod away from the ball and then bring it close to the ball for a second time. This time the ball is driven away (repelled), as in the illustration.

Repeat this experiment, using a rod of glass which has been rubbed with silk.

You probably found that the glass rod rubbed with silk also attracted and repelled the pith ball, but not so strongly as did the rubber rod rubbed with fur or wool. If you repeat these experiments on different days, you will notice that you get the best results on days when the air in the room is relatively dry. But what is the explanation for the behavior of the pith ball and the rods? You can answer this question after a little more experimenting.

Exercises. Hang from a support a rubber rod that has been rubbed with fur or wool. Rub a second rubber rod in the same manner and bring it near the first one, as shown below. Do the rods attract or repel one another?

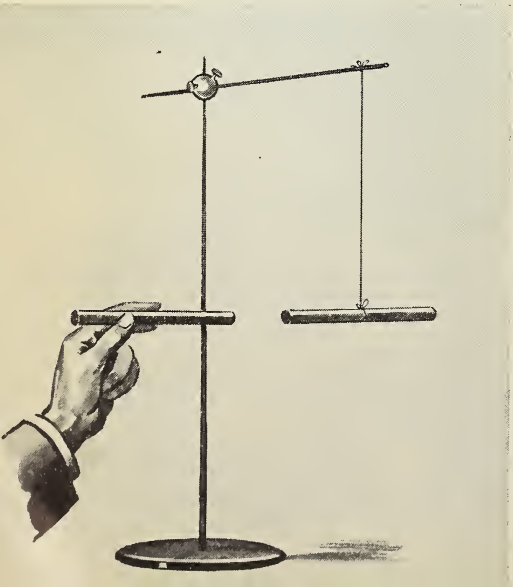
Repeat this experiment, using two glass rods that have been rubbed with silk. What happens in this case?

Try one more combination. Hang the rubber rod that has been rubbed with fur or wool on the support and bring up to it a glass rod that has been rubbed with silk. What happens this time?

The above experiments show that a hard rubber rod which has been charged with electricity by rubbing with fur or wool will *repel* another similarly charged rubber rod. In the same way, a glass rod charged by rubbing with silk will *repel* another similarly charged glass rod. A charged rubber rod and a charged glass rod, on the other hand, *attract* one another.

Franklin did these and similar experiments and decided that there are two different kinds of

With this equipment you can test the effects of charged rods on each other



electricity. Since the charges on the glass and rubber rods seemed opposite in character, Franklin called the charges on the glass rod *positive electricity* and the charge on the rubber rod *negative electricity.* Since the electricity seemed to stay on the rods after they were once charged, it was named *static electricity.* "Static" means "at rest."

Our observations on charged rods bring out certain important facts about the behavior of electricity. Let us round up this information before going on with our investigations. We shall need to remember the following points if we are to understand the nature of electricity.

1. *An uncharged body is attracted by a charged one.* We found that little bits of paper and pith balls, when uncharged with electricity, are attracted by either a charged glass rod or a charged rubber rod.

2. *When two bodies are charged alike* (*both positive or both negative*), *there is a repelling force between them.* We found, for example, that there is a repelling force between a charged rubber rod and another charged rubber rod. We also found that there is a repelling force between a charged glass rod and another charged glass rod.

3. *When two bodies carry unlike charges* (*one positive and the other negative*), *there is an attractive force between them.* We found, for example, that there is an attractive force between a charged rubber rod and a charged glass rod.

4. *When an uncharged body is touched by a charged one, part of the charge passes to the uncharged body.* Remember how the pith ball was first attracted to the rubber rod and then repelled? The charged rubber rod contained negative electricity. The pith ball was uncharged. The two, accordingly, were attracted to one another. After

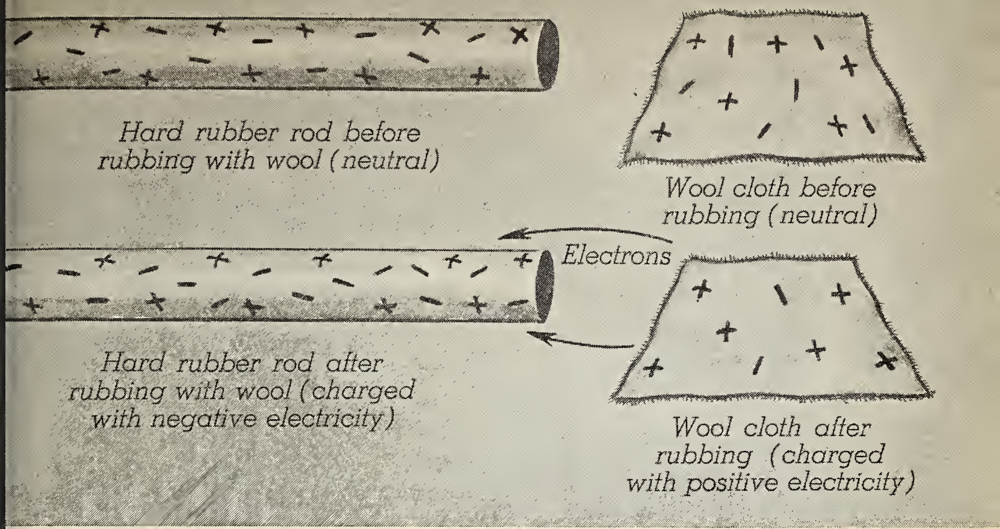
touching the charged rubber rod, however, the pith ball became charged with negative electricity from the rod. Since both the rod and the pith ball were then charged with negative electricity, they repelled one another.

You can briefly summarize all these observations as follows: *Bodies with like electric charges repel one another. Bodies with unlike charges attract one another. Bodies charged with either kind of electricity attract bodies that are not charged at all.* This is the law of electric charges.

The Theory of Electrons. Scientists are not content merely with discovering the laws that make forces and materials do what they do. They try also to discover *why* the laws operate. In trying to understand why electric charges behave in the manner we observed above, scientists have advanced what is known as the theory of electrons. Strictly speaking, no theory can be completely proved to be true, because it exists only in the minds of the people who hold it. But all worthy theories are based on facts which are known through experimentation and observation; all worthy theories help us to understand the meaning of such facts.

The theory of electrons is a worthy theory because it helps us to understand why like charges of electric energy repel, and unlike charges attract. According to this theory, all matter is supposed to be made up of tiny particles called *atoms*, which in turn are made up of tinier particles called *electrons* and *protons*. Electrons are particles of negative electricity and protons are particles of positive electricity.

An atom is normally thought to have just as many electrons as protons. These particles of negative and positive electricity therefore balance one another so that the atom

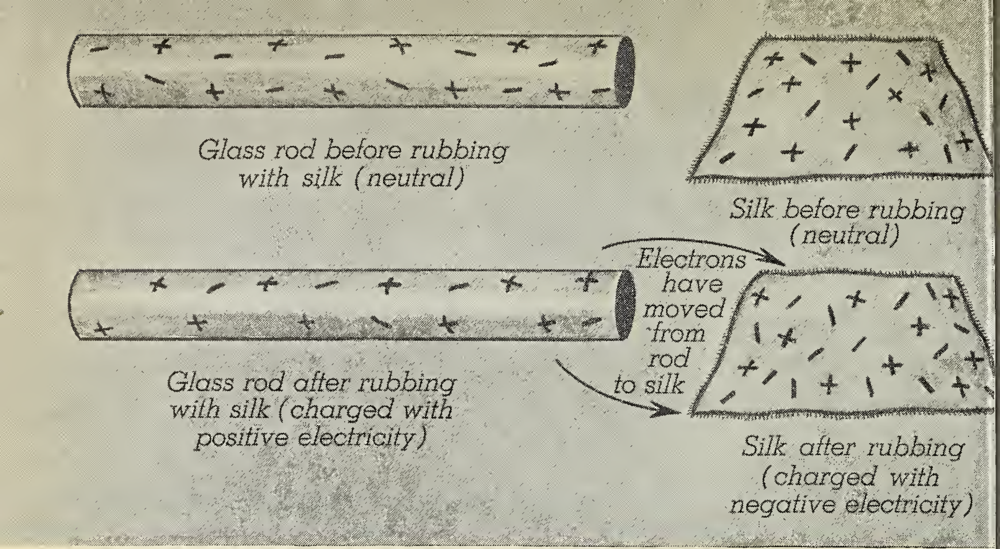

Hard rubber rod before rubbing with wool (neutral)
Wool cloth before rubbing (neutral)
Electrons
Hard rubber rod after rubbing with wool (charged with negative electricity)
Wool cloth after rubbing (charged with positive electricity)

is what happens, according to the theory of electrons, when a hard rubber rod is rubbed by a woolen cloth

is neither negative nor positive, but *neutral.* Electrons, however, are very active. They can move easily from one material to another, thus destroying the electric balance.

How the Theory of Electrons Explains the Behavior of Electric Charges. Let us apply this theory to the experiments which you have just performed. Before you rubbed the hard rubber rod with fur or wool, it was neutral. In other words, it contained the same number of negative (electrons) and positive (protons) particles. When rubbed with wool, however, it became negatively charged by taking some of the electrons from the fur or wool. The fur or wool, on the other hand, became positively charged because it was left with fewer electrons than protons. The diagram above will show what is supposed to have happened.

In the same way, when you rubbed a glass rod with a silk cloth there was a movement of electrons. But in this case the electrons moved from the rod to the cloth, rather than the other way round, as in the case of the rubber rod


Glass rod before rubbing with silk (neutral)
Silk before rubbing (neutral)
Electrons have moved from rod to silk
Glass rod after rubbing with silk (charged with positive electricity)
Silk after rubbing (charged with negative electricity)

This is what happens, according to the theory of electrons, when a glass rod is rubbed with a silk c

which you rubbed with fur or wool. The result was that the glass rod became charged with positive, and the silk cloth with negative, electricity. See the illustration above.

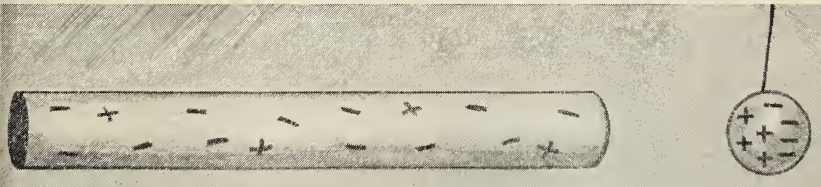
Since rubber rods rubbed with fur or wool are always charged with the same kind of electricity (negative), they always repel one another as you discovered in the experiment on page 310. Since glass rods rubbed with silk are also always charged with the same kind of electricity (positive), they also always repel one another. Since charged rubber and glass rods always contain the opposite kinds of electricity, they always attract one another. Do you see then how the theory of electrons helps to explain your observations on charged rods?

Can this theory explain your experiment with the charged rubber rod and the pith ball? Let us see. When the rubber rod (rubbed with fur or wool and so charged with negative electricity) was brought near the pith ball (a neutral substance made up of equal numbers of electrons and protons), the numerous electrons in the rod repelled the less numerous electrons in the pith ball to the far side of the ball, as shown in the top figure of the illustration below.

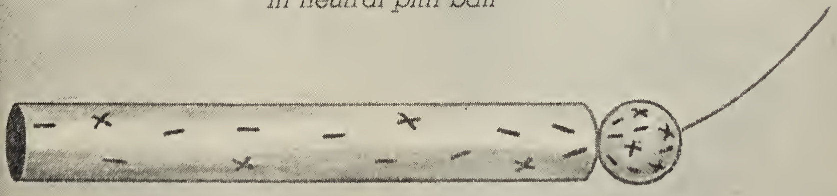
This allowed an attraction between the negatively charged rod and the side of the pith ball which carried the positive charge. Owing to the attraction, the pith ball moved toward the rod. When the two came in contact, as shown in the middle figure, there was a rush of electrons from the rod to the ball until the ball came to have more electrons than protons. It thus became negatively charged, with the result that it was repelled by the rod, which was also negatively charged, as shown in the bottom figure.

Uses for Electric Charges. It is easy to see that the energy on the charged rods which we have studied in this section

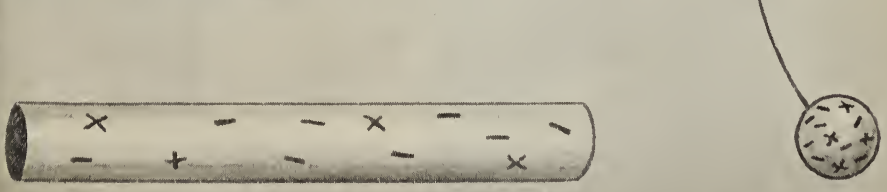
s is how the theory of electrons explains
what happened in the experiment on page 309



Electrons in negatively charged rod repel electrons in neutral pith ball



Electrons move from rod to pith ball



Negatively charged pith ball repelled by negatively charged rod exerts either a push or a pull on certain kinds of objects. In other words, it exerts force. It is this force of electric energy that man has put to work at so many different practical tasks in the modern world. Let us next see how this feat has been accomplished.

CURRENT ELECTRICITY AND WORK

Conductors and Insulators. Not all kinds of materials hold an electric charge in the way that hard rubber and glass do. You cannot, for example, charge a metal rod by holding it in your hand and rubbing it with silk or fur or anything else. Any charge that is formed on metal runs off. Metals, accordingly, are called *conductors* of electricity because they carry, or conduct, it away. Substances like glass, rubber, silk, paper, and pith, however, are called *nonconductors* or *insulators* because they do not conduct electricity away. On such substances electricity tends to be "static," or at rest.

How Electricity Moves. A simple experiment will show you how electricity can be made to move.

Exercise. Charge a rubber comb with electricity by rubbing it vigorously with a piece of flannel or the sleeve of your sweater. Test it with a bit of paper to see if it is truly charged. Then rub the comb with your bare hand and see if it will still pick up a bit of paper. What happened to the electric charge?

The electric charge on the rubber comb moved out of the comb when you rubbed it with your bare hand because your body is a good conductor of electricity. Whenever an insulator charged with electricity comes in contact with a conductor, the electricity moves into the conductor. As soon as electricity begins to move, it ceases to be static electricity. It becomes what is known as *current electricity*.

There was a time when it was believed that static electricity and current electricity were two different things. Now it is believed that they are the same and that both are associated with electrons. In static electricity the electrons may be stored on a nonconducting body as a negative charge; or removed from such a body, leaving a positive charge behind. In current electricity the electrons are not stored, but flow along a conducting body. When this flow of electrons is properly controlled, it may be made to furnish heat and light, to bring about chemical changes of importance in industry, to turn motors, and to carry signals by means of telegraph and radio.

Though we take current electricity as a matter of course today, there were long ages during which men knew nothing about this mighty source of energy. Perhaps the ancients knew, as every child of the modern world knows, that electricity can be stored in the human body by merely scraping the feet on a rug. They probably knew that this stored electricity could be suddenly discharged in a spark merely by touching an object in the room. But they did not know that electric energy could be made to flow in a steady stream from one place to another.

This lineman is busy with his part in the task of making current electricity move throughout the civilized world

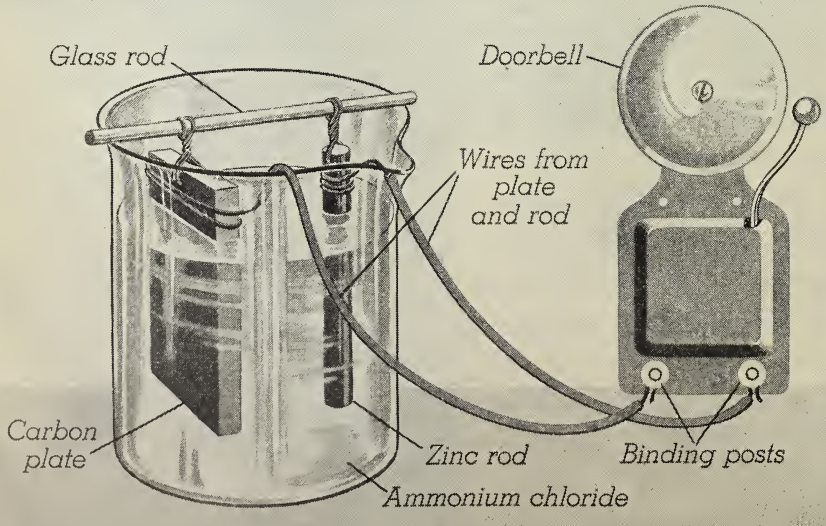
New England Telephone and Telegraph Co.

Humanity had to wait for this information until an Italian scientist, Alessandro Volta (1745–1827), showed that electricity could be produced in a steady current through chemical activity. You have already followed in Volta's footsteps when you made the experiments in Chapter Four to prove that chemical activity on metals produces an electric current. Another simple experiment will help you further in understanding this important fact.

Exercise. Obtain from a dealer in electrical supplies a carbon plate and a zinc rod. Nearly fill a quart fruit jar or glass beaker with water in which as much ammonium chloride as the water will absorb has been dissolved. Hang the carbon plate and the zinc rod in the solution, but do not let them touch. Attach copper wire to the ends of the plate and the rod, as shown below. Connect the other ends of the wires to an ordinary electric bell, and the bell will ring.

In the above experiment you made what is known as a "wet cell" electric battery, the same kind of battery which is often used to furnish the current to ring doorbells in

With this equipment you can produce a steady current of electricity



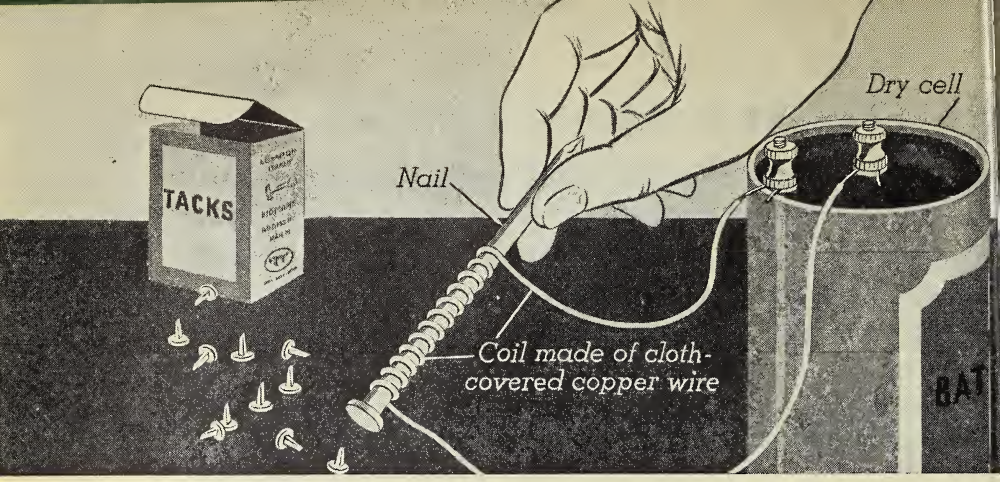
homes and which serves many other purposes in the modern world. When Volta made the first wet cell, and through it demonstrated the possibility of producing a steady current of electricity, he made it possible for man to harness a giant which had been lying idle for long ages of time.

Magnetism. Before we can understand how current electricity can be changed into the energy of motion that rang the bell in our experiment, we must understand something about magnetism. Probably long before the Greeks knew anything about the electric properties of rubbed amber, ancient peoples knew that a certain kind of iron compound had the power to attract small bits of iron or steel. This peculiar iron compound was called magnetite, a word from which we get the word *magnet*. A magnet is merely such a body as has this power to attract iron or steel, and the attraction is known as *magnetism*.

Magnetism, like electricity, was not put to any wide use until long after it was discovered. Not until it was learned that *any kind of iron can be made into a magnet merely by passing an electric current through it* did magnetism become a highly useful servant of man. A simple experiment will show you how easily a magnet can be made with the help of an electric current.

Exercise. Wind a coil of cloth-covered copper wire round an iron nail. Connect the ends of the coil to an electric battery, as shown on page 320. Place some carpet tacks near the nail. What happens? Disconnect one of the wires and the battery, and repeat the experiment. What happens now?

By turning magnetism on and off merely by turning the electric current on and off, man has in the so-called *electromagnet* an instrument that has many uses.


TACKS
Nail
Dry cell
Coil made of cloth-covered copper wire
BAT

With this equipment you can turn an ordinary nail into an electromagnet

How an Electric Bell Rings. One of the simplest mechanisms for changing electric energy into the energy of motion is an electric bell. This instrument operates through the use of an electromagnet. Perhaps you have sometime taken the cover off an electric bell. If so, the picture on the opposite page should be familiar to you.

Notice the two coils of wire, each wound around a *core* of soft steel. Each core is fastened firmly at one end to a bar of soft steel, called a *yoke*. This makes the free end of each core an electromagnet whenever an electric current passes through the wire. The *clapper* is so attached to a piece of metal (*armature*) that it may move back and forth. The armature, like the cores of the magnet, is made of soft steel. When no current is flowing, it is held away from the cores by a *spring*. This spring holds the armature firmly against a *contact screw*.

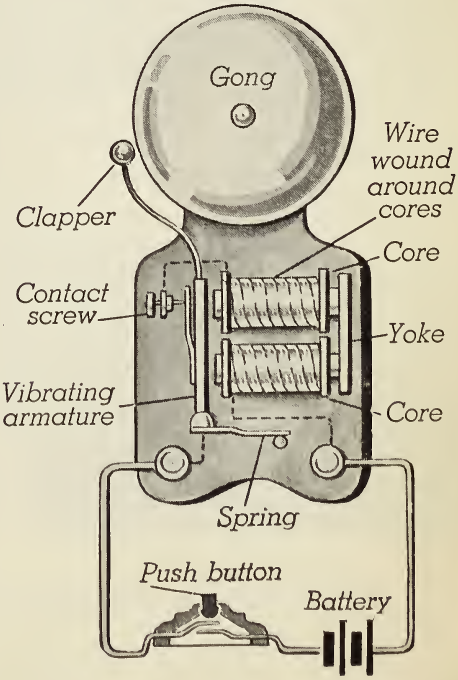
Notice that the *push-button switch* is so made that when the button is pushed, a continuous current of electricity passes from the battery through the coils of wire, thus turning the cores into magnets. Immediately the magnetic force pulls the armature away from the contact screw to the ends of the cores, thus making the clapper strike the gong.

When this happens, the electric circuit is broken because the current cannot flow unless the contact screw and the armature are connected. The cores, accordingly, lose their magnetism and the spring pulls the armature back against the contact screw. Again the circuit is closed, the armature is attracted toward the magnet, the clapper strikes the gong, and the circuit is broken. Over and over again, and with extreme rapidity, this process is repeated as long as the button of the switch is held down. The result is that the armature vibrates and the bell rings.

Electromagnets and the Generation of Electricity. The practical applications of the electromagnet only begin with the doorbell. The telephone, the telegraph, the electric motor, and many other machines use electromagnets for changing electric energy into the energy of motion. We shall learn more about some of these machines in the next chapter, but we should realize at this point that modern life would be very different from what it is if this useful device had not been invented.

Turning electric energy into the energy of motion, as useful as it is, is only part of what the electromagnet does for us. Turning the energy of motion into electricity is the other part. In one of the most important discoveries ever made by man, Michael Faraday (1791–1867), an English scientist, demonstrated that *not only can electricity be*

This diagram shows how an electric bell works

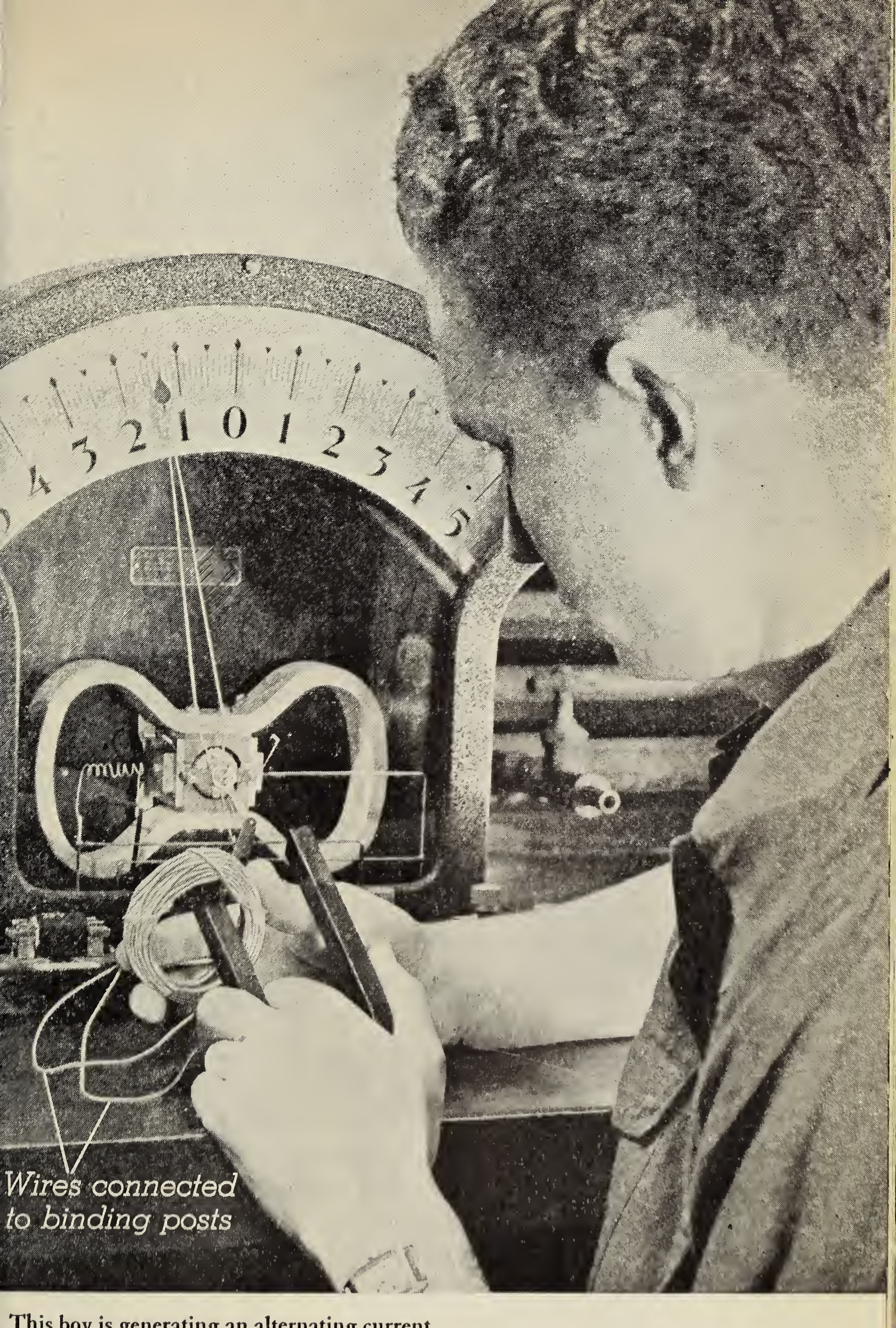


made to produce magnetism, but magnetism can be made to produce electricity. With this discovery, man was able to use electricity to an extent that would have been impossible had the discovery never been made. Let us see why.

Before we can understand what Faraday learned about magnets we must learn a little more about magnets ourselves. In making an electromagnet, only *soft* iron or *soft* steel can be used. These materials do not hold their magnetism after the current of electricity flowing through the coil of wire is turned off. If they did hold their magnetism after the current stopped flowing, it is easy to see that they would be useless in such an instrument as a doorbell.

Hard iron and *hard* steel, on the other hand, will hold their magnetism for some time after being magnetized. For this reason magnets made of these materials are known as *permanent magnets.* You have probably noticed that a toy horseshoe magnet made of hard steel holds its magnetism. Though useless in devices such as doorbells, where the magnetism must be rapidly turned on and off, permanent magnets are useful in other electrical devices. Which brings us back to Faraday's great discovery.

While experimenting with permanent magnets, Faraday learned that when he moved a loop of wire between the prongs of a horseshoe magnet, an electric current was produced, or generated, in the wire. As the loop repeatedly cut across the lines of magnetic force, the electric current repeatedly changed its direction in the wire. It behaved like a lion pacing back and forth in a cage, excepting that it moved much more rapidly than any lion has ever moved. Such an electric current is known as an *alternating current.* It is quite different from the electric current that flows from an ordinary wet or dry battery. Such a current flows in one unchanging direction and is known as a *direct current.*


4 3 2 1 0 1 2 3 4 5
Wires connected to binding posts

This boy is generating an alternating current of electricity with a magnet and a coil of wire

Exercise. How to generate an alternating current of electricity with a magnet: Obtain a sensitive galvanometer, which is a simple instrument for measuring the flow of an electric current. Connect a coil of ordinary insulated wire to the galvanometer, as shown on page 323. Move the coil quickly over one prong or between the two prongs of a horseshoe magnet and notice what happens to the needle of the galvanometer. Then move the coil quickly back to its starting position and notice what happens to the needle of the galvanometer. What evidence do you get of the generation of an electric current in the coil by these movements? What evidence do you get that the current alternates?

Faraday's discovery of *electromagnetic induction*, as he called this method of producing electricity, laid the foundation for our modern widespread use of this form of energy. So long as electricity could be generated only in batteries, its use could never be very great. Batteries are expensive because the materials in them are rapidly consumed to produce a relatively small amount of electric current. But when Faraday demonstrated that merely twirling a loop of wire within the prongs of a permanent magnet will produce electricity just as well as a battery, a whole new world of possibilities loomed up.

When this discovery was made, most of the rivers of the world were running idly to the sea. Most of the energy-producing minerals were yet to be mined. These vast reserves of energy were just waiting to turn the wheels that would twirl the wires in which electric currents would be generated cheaply by electromagnetic induction. The electric generator, most useful of all electrical devices, was the natural result of Faraday's discovery. With its invention the age of electricity was born.

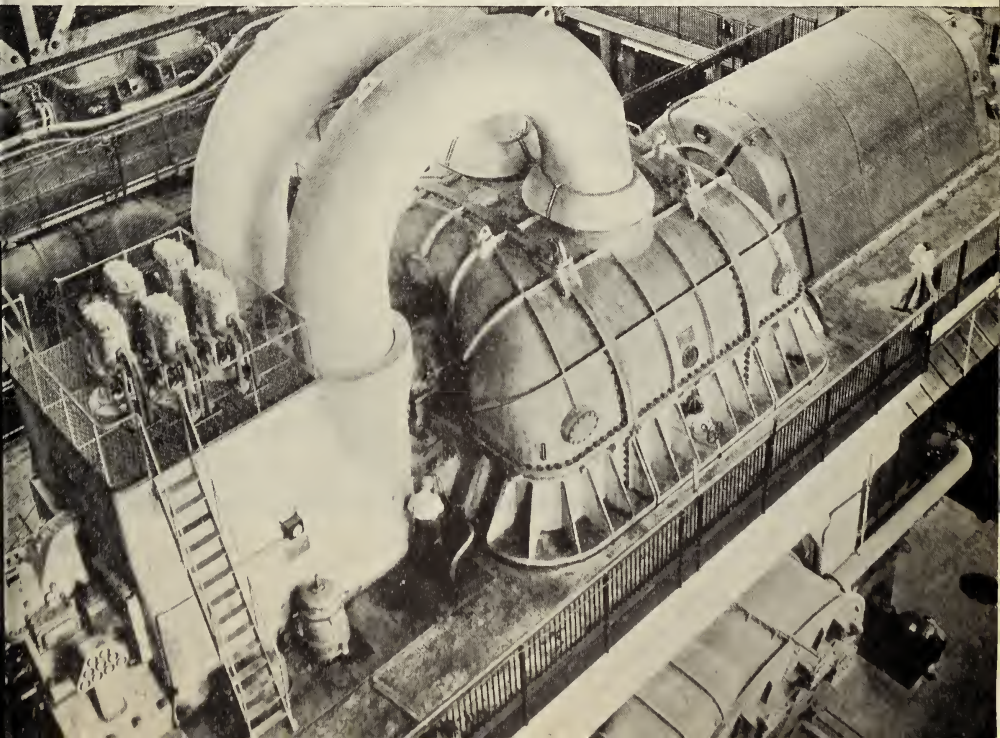
The Electric Generator. The electric generators, or *dynamos,* shown below are practical applications of the principle you demonstrated in the experiment on the opposite page. In every electric generator there is a revolving armature which consists of a coil of wire wound round a soft iron core. The armature is made to turn between powerful magnets, generally with the energy of running water or steam. This makes the wires of the coil rapidly and continually cut through the magnetic field, with the result that electricity is generated in them. The electricity is then carried away by wires and put to a thousand uses. Let us next see what some of these uses are.

ELECTRICITY IN THE HOME

Importance of Electricity in the Home. In the last chapter we saw how the invention of the electric light brought a new era in the history of artificial lighting. The electric

These mighty generators produce electricity by electromagnetic induction

Westinghouse Electric Manufacturing Co.



light was the first device for using electric energy in the home. Other devices for using this energy followed in quick succession. The electric iron took over the work of the stove-heated flatiron. The vacuum cleaner took over the work of the broom.

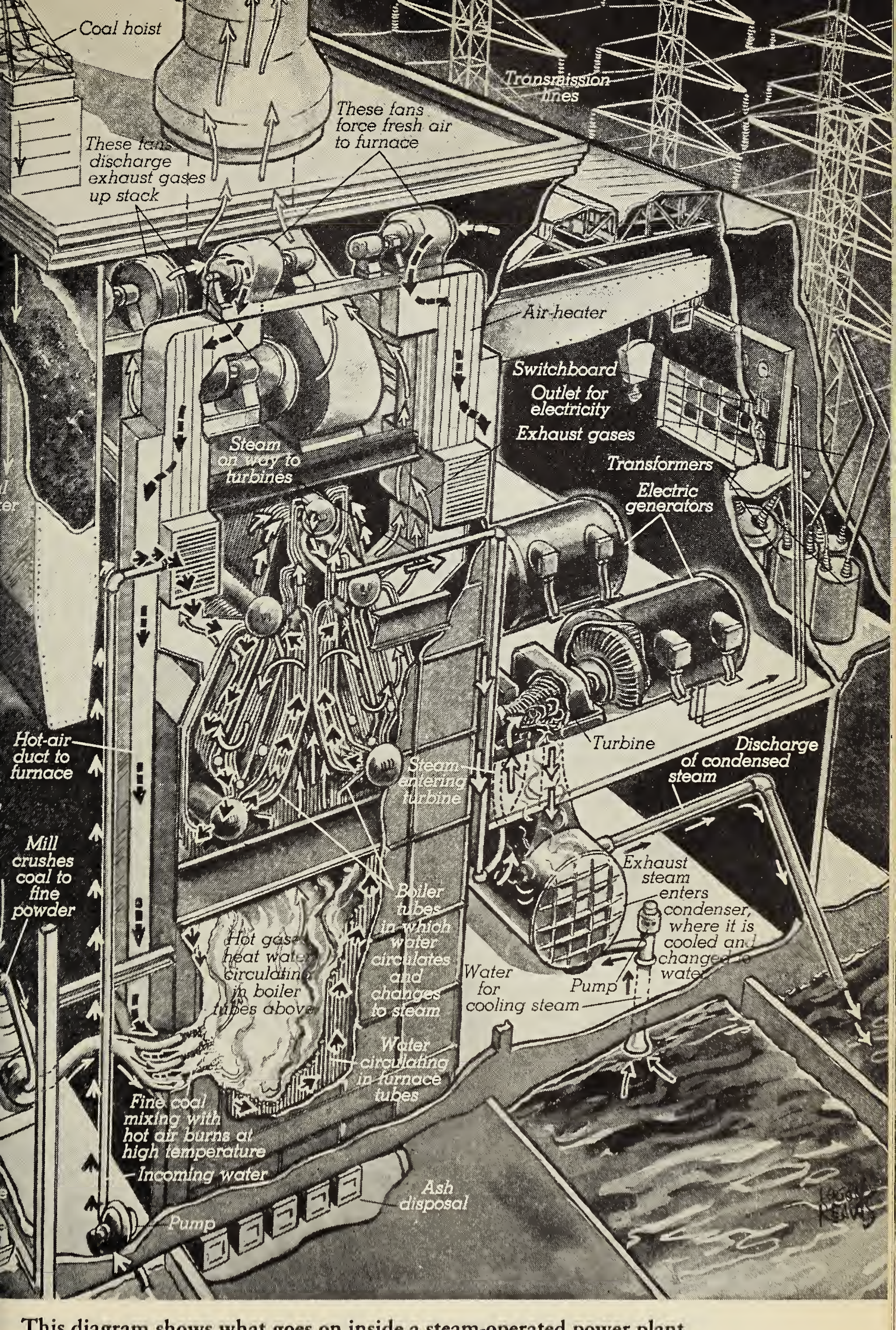
Electric fans, toasters, washing machines, pumps, sewing machines, stoves, and many other similar instruments entered the home, first as luxuries, then as accepted necessities. Today, life would seem strange and difficult to a great many people if these devices should suddenly disappear.

Exercise. Make a tour of your own home and see how many different kinds of electrical instruments are in use there. How many of these could you comfortably live without?

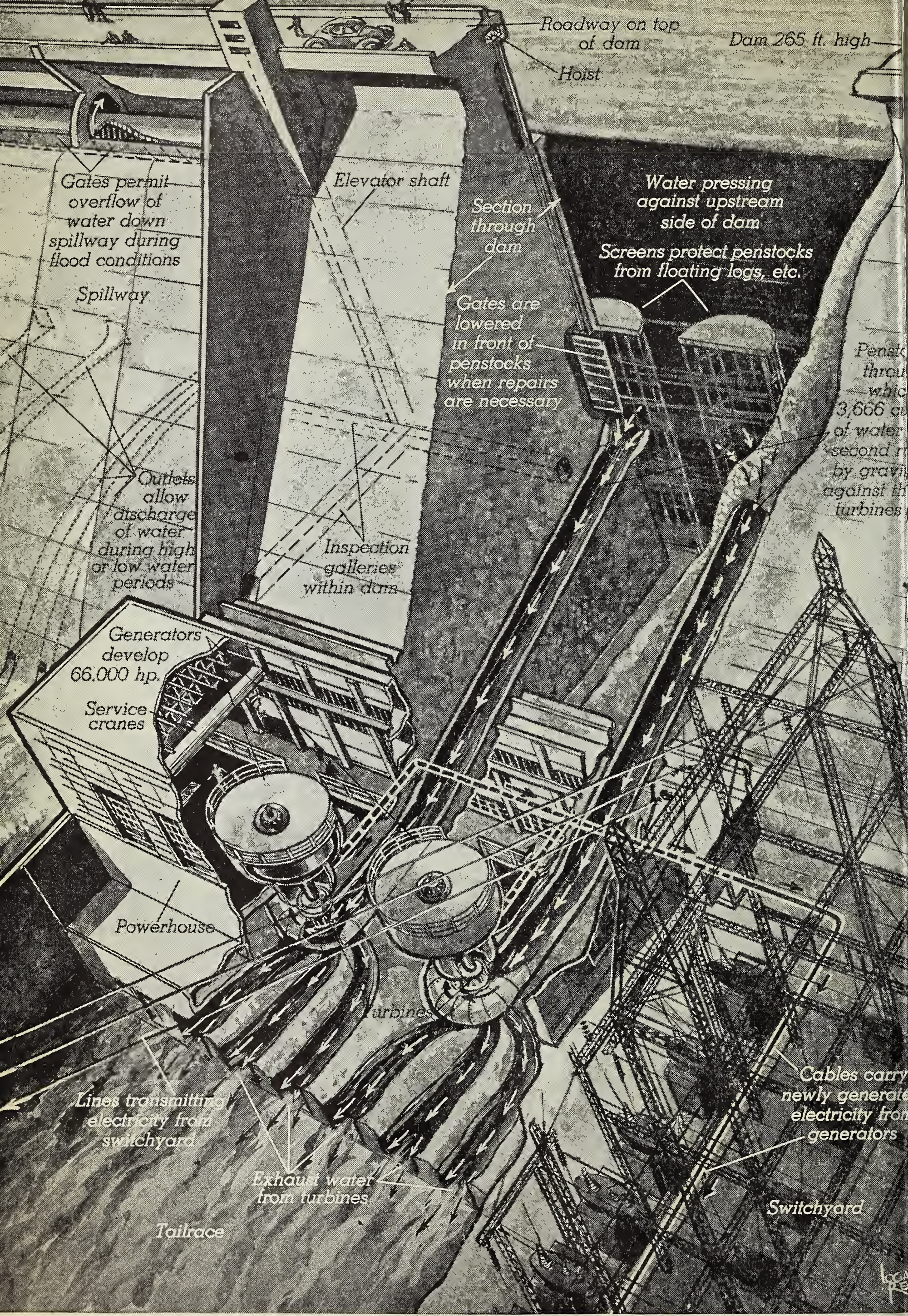
Electric Power Plants. The electricity used in the home comes from a power plant which is run, as we learned in the last section, by steam or running water. A country family may own its own individual small power plant, but a city family generally gets its electricity from a large plant that supplies a large number of homes.

The drawing on the opposite page shows a large steam-operated electric power plant. Notice that it is located on a river where barges can easily bring in the coal that the greedy monster consumes each day. Notice the boilers in which the steam is generated to run the immense steam turbines, which in turn run the generators that make the electricity.

The drawing on page 328 shows a water-operated power plant (*hydroelectric plant*). This sort of plant is built below a dam on a river. The water piles up behind the dam and is drawn down into the plant as needed through tunnels or pipes. There it is made to turn great water turbines which are similar to the turbines studied in Chapter


Coal hoist
Transmission lines
These fans force fresh air to furnace
These fans discharge exhaust gases up stack
Air heater
Switchboard
Outlet for electricity
Exhaust gases
Steam on way to turbines
Transformers
Electric generators
Turbine
Discharge of condensed steam
Hot-air duct to furnace
Steam entering turbine
Mill crushes coal to fine powder
Boiler tubes in which water circulates and changes to steam
Exhaust steam enters condenser, where it is cooled and changed to water
Hot gases heat water circulating in boiler tubes above
Water for cooling steam
Pump
Water circulating in furnace tubes
Fine coal mixing with hot air burns at high temperature
Incoming water
Ash disposal
Pump

This diagram shows what goes on inside a steam-operated power plant


Roadway on top of dam
Hoist
Dam 265 ft. high
Gates permit overflow of water down spillway during flood conditions
Spillway
Elevator shaft
Section through dam
Water pressing against upstream side of dam
Screens protect penstocks from floating logs, etc.
Gates are lowered in front of penstocks when repairs are necessary
Penst
throu
whic
3,666 c
of water
second r
by gravi
against th
turbines
Outlets allow discharge of water during high or low water periods
Inspection galleries within dam
Generators develop 66,000 hp.
Service cranes
Powerhouse
Turbines
Cables carry newly generat
electricity fro
generators
Lines transmitting electricity from switchyard
Exhaust water from turbines
Tailrace
Switchyard

This diagram explains how the great Norris Dam hydroelectric plant works

Nine, excepting that they are operated by running water rather than by moving steam. The turbines turn the electric generators which make the electricity, just as in the case of the steam-operated power plant.

How Electricity is Measured. Electricity is generated in immense quantities in such large modern power plants. Like all other forms of energy, the electric energy so generated can be measured in terms of what it can do. The strength of an electric current, for example, can be measured by the rate at which it flows through a wire.

Just as water may flow out of a pipe at the rate of, say, one gallon or one hundred gallons a second, the rate of electricity flowing through a wire may vary. The flow of electricity cannot, of course, be measured in gallons. It is measured in amperes, a term taken from the name of André Ampère, a French student of electricity. *An ampere is a definite amount of electricity that passes through a wire in one second.*

As an electric current flows through a wire there is always some resistance. Just as water flows out of a large pipe with less resistance than out of a small pipe, electricity passes more easily through a coarse or a short wire than through a fine or a long one. Wires of different metals likewise offer different resistance to the movement of electric currents. Copper, which is used so widely for carrying electricity, offers very little resistance. *Resistance to electric currents provides another way of measuring their strength, and the ohm is a definite unit for making this measurement.* This term comes from the name of Georg Ohm, a German scientist.

Force, of course, is necessary to drive an electric current against a resistance. The third unit for measuring electricity measures this force. It is called the *volt* after Alessandro Volta, the Italian scholar whom we have already mentioned. Just as we measure the force of water in a pipe as so many pounds of pressure per square inch, we measure the force of electricity in a wire as so many volts. *A volt is defined as the force necessary to drive one ampere of current through the resistance of one ohm.*

Another term of electrical measurement which you have probably heard is the *watt*, named after James Watt, the Scottish engineer who invented the steam engine. The watt is a measure of the rate at which electric energy works. The measurement of the rate of work is very important in determining the strength of any kind of energy. Let us say, for example, that by hard work you can chop a cord of wood in eight hours. A woodsman is stronger than you and is able to do the same job in four hours. He does it in less time than you can do it because he is more "powerful" than you. The term "power" is applied to the rate of doing any kind of work.

The watt is the unit of electric power. It is the quantity of electricity that flows past a given point in one second (amperes) multiplied by the pressure, or force, with which the current is flowing (volts). People who work a great deal with electricity are continually dealing with the measurement of electricity in watts. They find it convenient to remember the definition of a watt simply as *amperes times volts equals watts.* An ordinary dry battery, for example, produces electricity with the force of about 1½ volts and a flow of about 20 amperes. The power of such a battery is therefore about 30 watts ($1\frac{1}{2} \times 20 = 30$).

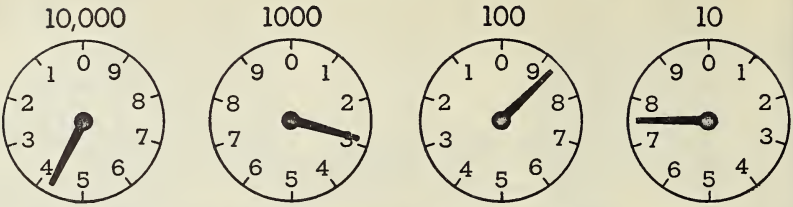
How We Pay for Electric Power. These units for measuring electricity mean very little to the average man. It

Galloway

In the modern home electricity does much of the work

would save him money on his electricity bill if he knew a little more about them. It would be well for him to know at least that an electric-heating device, such as an iron or toaster, uses about twelve times as many watts during the same period of time as a 40-watt electric bulb. The motor of a modern vacuum cleaner, on the other hand, uses very little more current than a 40-watt bulb. An ordinary electric washing machine uses less than half as many watts as an electric toaster.

When we pay for electric energy in the home, we pay for energy to do work at a certain rate for a certain period of time. An electric toaster or iron uses about 500 watts an hour. If such an instrument runs for 2 hours, it uses 1000 watts, or 1000 *watt-hours*, as it is generally called. A watt-hour is merely 1 watt of current used for 1 hour.



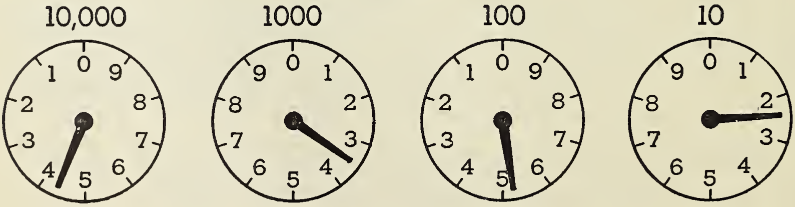
At the beginning of a month the dials on an electric meter looked like this

Since the watt is a very small unit, and many of them are used every day in the home, the power company groups watts in units of one thousand (*kilowatts*). A *kilowatt-hour* is 1000 watts of current used for 1 hour. An electric toaster or iron operating for 2 hours uses 1000 watt-hours, or more simply 1 kilowatt-hour.

Exercise. Suppose that during one day an electric iron was used in your home for 1 hour, and an electric toaster for 1 hour. During the evening five 40-watt lamps were burned for 3 hours. At 5 cents a kilowatt-hour, how much would the electricity cost for the day?

How to Read an Electric Meter. The illustration at the top of this page shows the dials on the face of the meter which measures the electric current that comes into a house. If you have such a meter in your house, you can easily read it and check up on the bill which the power company sends.

At the end of the month the dials shown at the top of this page looked like this. How much electricity passed through the meter during the month?



This instrument works somewhat like the speedometer on an automobile. The pointer on the dial at the extreme right makes one revolution for every 10 kilowatt-hours of electricity that flows through it. The next dial to the left makes one revolution for every 100 kilowatt-hours; the next one revolution for every 1000 kilowatt-hours, and the next one revolution for every 10,000 kilowatt-hours. To read the meter, you merely copy the figures on the dial at which the pointers are pointing. If a pointer stands between two figures, you read the smaller figure. The reading on the meter in the illustration is thus 4287 kilowatt-hours.

Meters are generally read about every month, and bills are sent on the basis of the readings. The illustration at the bottom of page 332 shows the reading on the meter one month after the reading shown in the illustration at the top of the page. Notice that this reading is 4352 kilowatt-hours. How much electricity, then, was used during the month?

Electricity in the Modern World. Though you now come to the end of this chapter on electricity, you do not come to the end of electricity. This chapter has tried to explain the principles on which our use of electricity is based, and some of the more important applications of these principles. As you go on in this unit with the study of communication and transportation, you will learn about other important applications.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Electricity was unknown until Benjamin Franklin flew his famous kite.

2. Hard rubber rods which have been charged with electricity attract one another, because bodies with like charges of electricity attract one another.

3. A pith ball is always attracted by a charged body, such as a hard rubber rod that has been rubbed with silk.

4. Negative and positive electricity always repel one another.

5. Electrons and protons can now be seen through modern high-powered microscopes.

6. Substances like hard rubber and glass, which can be charged with electricity, are known as conductors.

7. Static electricity is different from current electricity because static electricity is made up of electrons and protons, and current electricity is not.

8. The ordinary wet battery is the easiest means of producing static electricity.

9. An electromagnet is merely a piece of hard iron or steel that attracts other pieces of iron or steel.

10. When a current of electricity is passed through a wire which is wrapped round a bar of iron or steel, the bar becomes a magnet by what is known as electromagnetic induction.

11. An ampere is a measure of the force with which an electric current is driven through a wire.

12. Electric power is the rate at which an electric current moves through a wire and is measured in volts.

13. The electric motor in a vacuum cleaner is more expensive to operate than an electric iron.

14. When the pointer on a dial of an electric meter stands between two numbers, you should read the number to which the pointer is closer.

Questions for Discussion

1. You may have heard electric bells in which the gong gives just one loud note instead of ringing steadily. What changes should be made in the bell shown on page 321 to make this possible?

2. What do you think might make a coal-operated electric power plant more economical than a hydroelectric one, and vice versa?

3. Do you think that some day all electricity may be produced by hydroelectric power? Why?

4. It has been said that the use of electricity has revolutionized methods of manufacturing. Do you believe this true or false? Why?

Things to Do

1. If you have an encyclopedia in your school library, see if you can find out more about what ancient peoples believed about electricity.

2. Take a trip to a near-by power station and see if you can discover what principles of electricity are applied there.

3. Find information about some large hydroelectric plants such as those at Muscle Shoals, Boulder Dam, Conowingo, Niagara Falls, or Keokuk, Iowa. Consider such questions as possible output, cost, area served, and whether the station is privately or publicly owned.

4. Look up information from which to write short life stories about Faraday, Volta, Ohm, Ampère, and Watt.

5. Make a study of the costs of electricity in your community and neighboring communities. What differences do you find? What explanations are there for these differences?

CHAPTER TWELVE

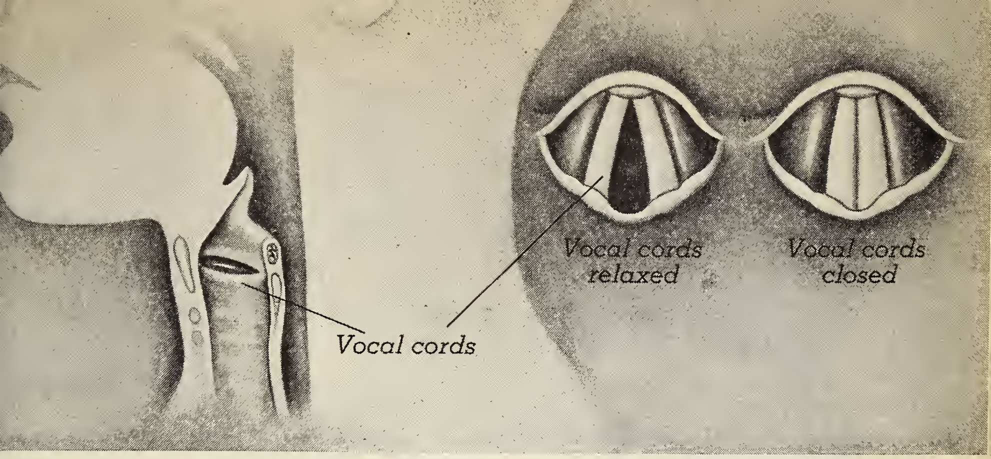
How Do We Employ Sound for Communication?

THE NATURE OF SOUND

Sound and Civilization. It has often been said that the brain and the larynx are the most wonderful organs in the human body. Both have vastly influenced the course of human history. With the help of his highly developed brain a man can think more complicated thoughts than any other living creature. With the help of his highly developed larynx a man can tell these thoughts to other men. Without these two organs it is very doubtful that mankind would ever have risen from savagery to civilization.

Civilization, as you can easily see, depends on the close co-operation of many different people. It depends to a very large extent on the ability of men to communicate their thoughts to one another. It is no accident that man is the only civilized creature and also the only creature that can read, write, and talk. Probably long before men were communicating with one another through writing they were laying the foundations of civilization through speech.

Speech is made possible by a form of energy called sound. From the earliest days when our distant ancestors began to attach special meanings to the wide variety of sounds they were able to produce in their throats, sound has been an important aid to human progress. It has never been more important than it is today. The telegraph, the telephone,

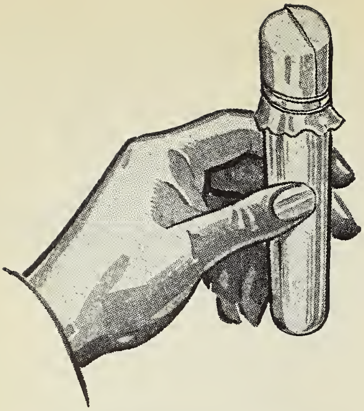


human larynx (left) helped to make civilization possible. The vocal cords (right) are relaxed when you are silent and taut when you are speaking

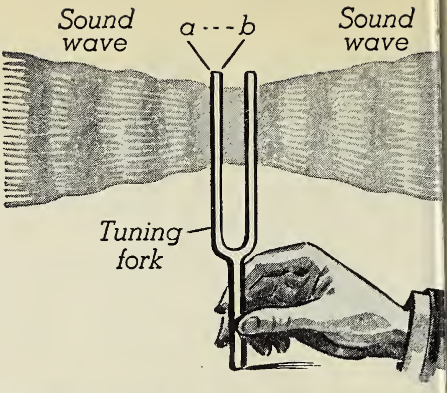
the radio, and many other devices which are based on the control of sound help to make modern life what it is. But before we can understand these devices we must understand the nature of sound.

How Your Voice Works. Let us first study the commonest way of producing what we call a sound. Hold your "Adam's apple" lightly with the fingers of one hand. Now read a few lines of this book out loud. Do you feel a vibration in your throat? It is this vibration that produces the sound of your voice.

You know that you possess a tube called the windpipe, which leads from your throat to your lungs. In your throat, at the upper end of this tube, is a small structure called the *larynx.* Across the larynx, as pictured at the top of this page, are the *vocal cords.* During ordinary breathing these cords are relaxed, but when you speak they tighten and air is forced between them. This causes them to vibrate (just as the tightened strings of a violin can be made to vibrate) and to produce the sounds which you call your voice.



With this equipment you can make a simple artificial larynx



This diagram shows how a vibrating tuni fork produces sound waves in the air

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Exercise. Make an artificial larynx by stretching two pieces of rubber from a toy balloon over the end of a narrow glass tube. The two pieces of rubber should overlap just a little, as shown above. Now blow vigorously into the open end of the tube. The vibrating rubber will produce a sound in the tube, much as the vibrating vocal cords in your throat produce the sound of your voice.

The Relationship of Vibration and Sound. You may experiment with other vibrating objects in the following easy experiments.

Exercises. Strike a large tuning fork gently with a wooden hammer, as shown on the opposite page. If you observe it closely, you may see the prongs, or points, vibrating. Touch the fork to the surface of the water in a shallow dish. What evidence do you get that the fork is vibrating?

For a second experiment, touch a pith ball attached to a string with a tuning fork that has just been struck with a wooden hammer. What evidence do you get in this case that the fork is vibrating?

Still other examples of the relationship of sound and vibration are familiar to everyone. You may draw a bow across the strings of a violin, or pluck the strings of a banjo or guitar. The strings vibrate and the result is sound. When you hit a drum, the drum top vibrates and sound is produced.

How Sound Travels. How is it that sound travels from a vibrating body to your ear? If you could examine the vibrating prongs of a tuning fork carefully, you would find that both prongs are vibrating at the same rate. A fork with the tone of middle C on the piano, for example, is known to vibrate at the rate of 256 vibrations per second. A fork with a higher note, or *pitch*, vibrates more rapidly; one with a lower note vibrates more slowly.

Study the diagram of the vibrating fork shown on page 338. Each prong moves first in the direction of *a* and then in the direction of *b*. As a prong moves toward *a* it presses against the air in that direction. As it moves toward *b* it presses against the air in that direction, and at the same time relieves the pressure on the air in the direction of *a*. The result is that with each vibration of a prong the near-by particles of air are first squeezed together and then allowed to spread farther apart. A vibrating motion is thus set up in the air as a result of the vibrating motion of the prong.

This back-and-forth motion of the air around the vibrating prong is carried along through the air farther and farther away from the prong. We call this motion

With this equipment you can show the relationship between vibration and sound

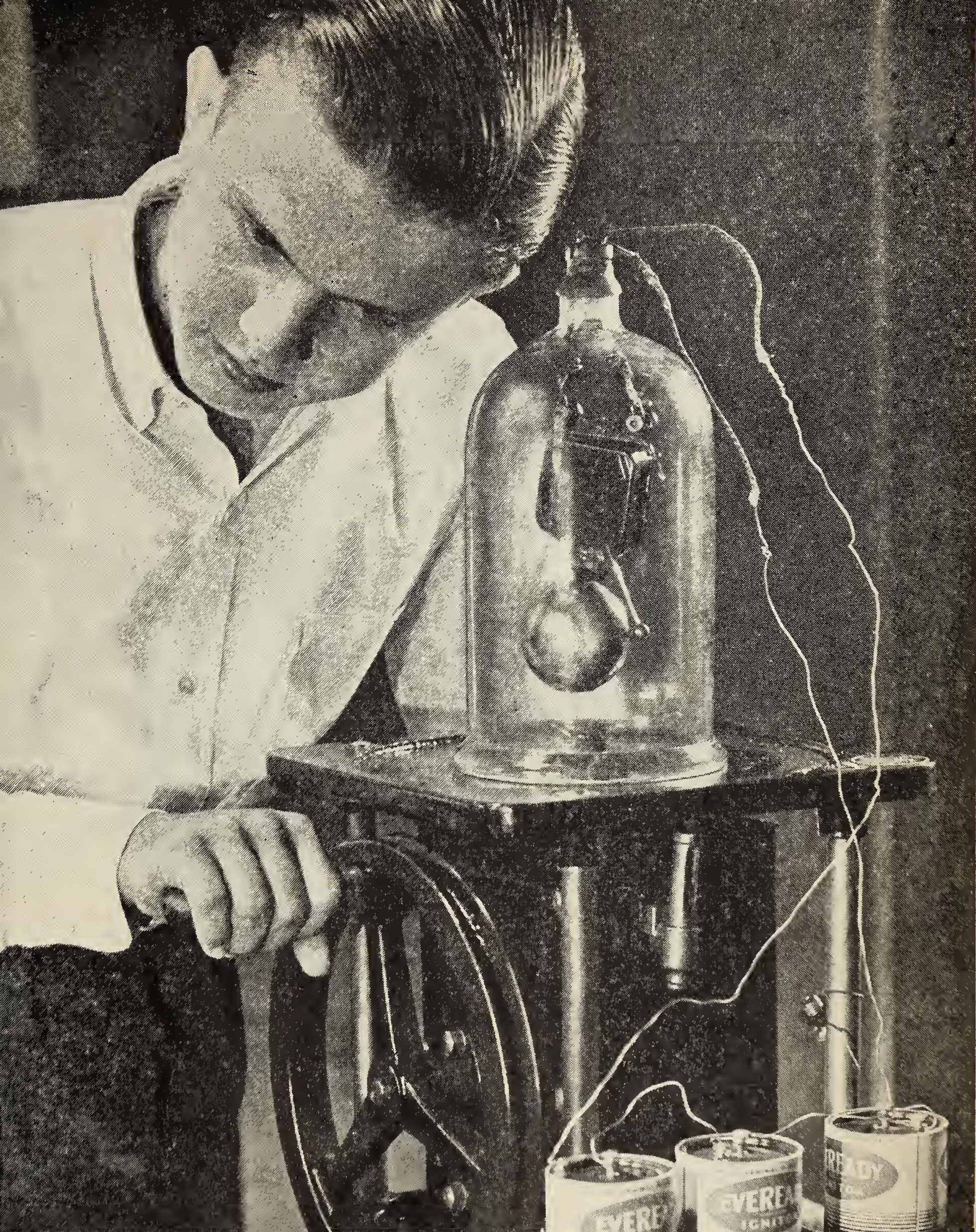
of the air a *sound wave.* Sound waves travel through air in much the same way that water waves travel over the surface of a smooth lake. Water waves, however, travel only at the surface of the water; sound waves travel in all directions.

Exercise. How to prove that air is a carrier of sound. Arrange an electric bell in a bell jar connected with an air pump, as shown on the opposite page. Connect the battery and the bell and notice that the bell rings clearly. Start the air pump and remove the air from the jar. The sound of the bell will become fainter and fainter until you cannot hear it at all. Allow air to enter the jar again. The sound of the bell will gradually grow louder.

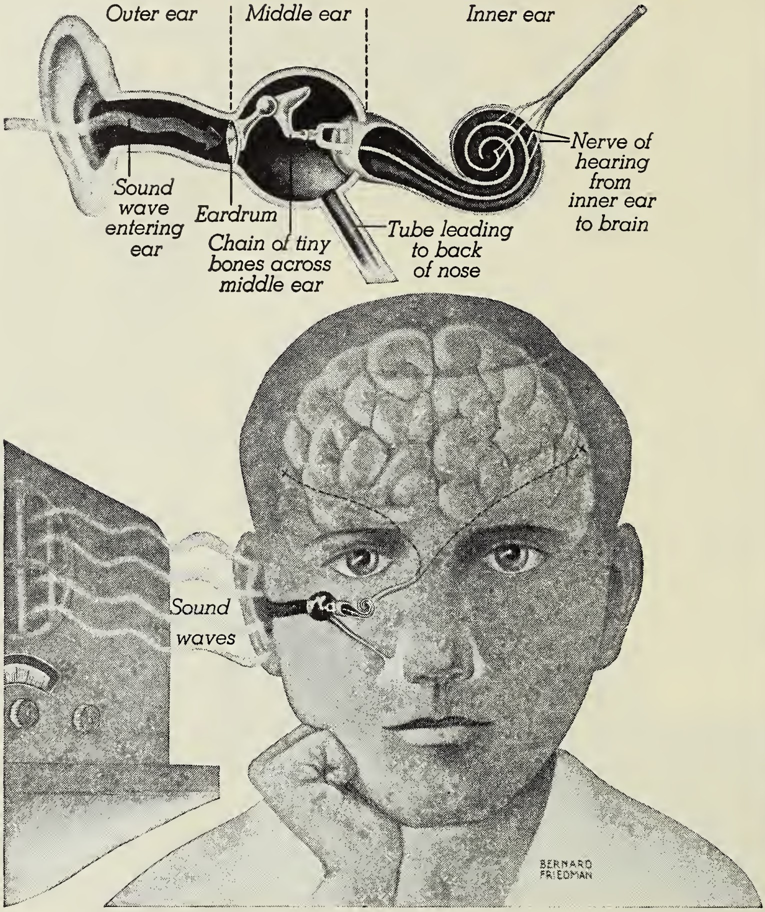
Loudness of Sound. So far we have discussed but one property of sound, its pitch. *The pitch of a sound, as you have learned, depends upon the number of times the vibrating body vibrates per second.* The faster a body vibrates, the higher will be its pitch; the slower it vibrates, the lower its pitch. Let us now turn to some other properties of sound.

If you strike a tuning fork lightly, it produces a soft sound; if you strike it harder, it produces a louder sound. The reason is that the harder blow causes the prongs to vibrate through a wider range. Thus it disturbs the surrounding particles of air more violently than does a lighter blow. This increased violence of vibration is interpreted by the ear as a louder sound. Remember, however, that *the vibrations of any given object are always at the same rate of speed, no matter how hard you strike it.*

Quality of Sound. A third property of sound is called quality. Tones from a violin and from a banjo may have the same pitch and loudness, yet they may be told apart.



This boy is proving that air is a carrier of sound


Outer ear
Middle ear
Inner ear
Nerve of hearing from inner ear to brain
Sound wave entering ear
Eardrum
Chain of tiny bones across middle ear
Tube leading to back of nose
Sound waves
BERNARD FRIEDMAN

This diagram shows how the ear and brain turn sound waves into the sensation of sound[1]

In the same way, two singers do not give out exactly the same sounds, even when they sing the same note with the same loudness. Imagine a great opera star singing high C. Now imagine some amateur singing it. The property of sound that makes it possible to tell one tone from another

[1] From Andress, Goldberger, Hallock, *Building Good Health.*

tone of the same pitch and loudness is called quality. It is the quality of sounds more than the pitch or the loudness that makes them pleasant or unpleasant to the ear.

How Fast Sound Travels. We all have seen a flash of lightning and then waited for the thunder. With the flash, sound waves start moving through the air. By counting the seconds between the flash and the time the sound reached our ears, we can tell whether the flash was near or far away. We know, too, that the puff of smoke from a distant locomotive may be seen a few seconds before the sound of it reaches our ears. Such common observations prove that *sound travels more slowly than light.*

Very careful measurements have shown that sound travels through air at the rate of about 1100 feet each second. If you can count an interval of five seconds between a flash of lightning and the sound of thunder, the flash was about 5500 feet (or a little more than a mile) away.

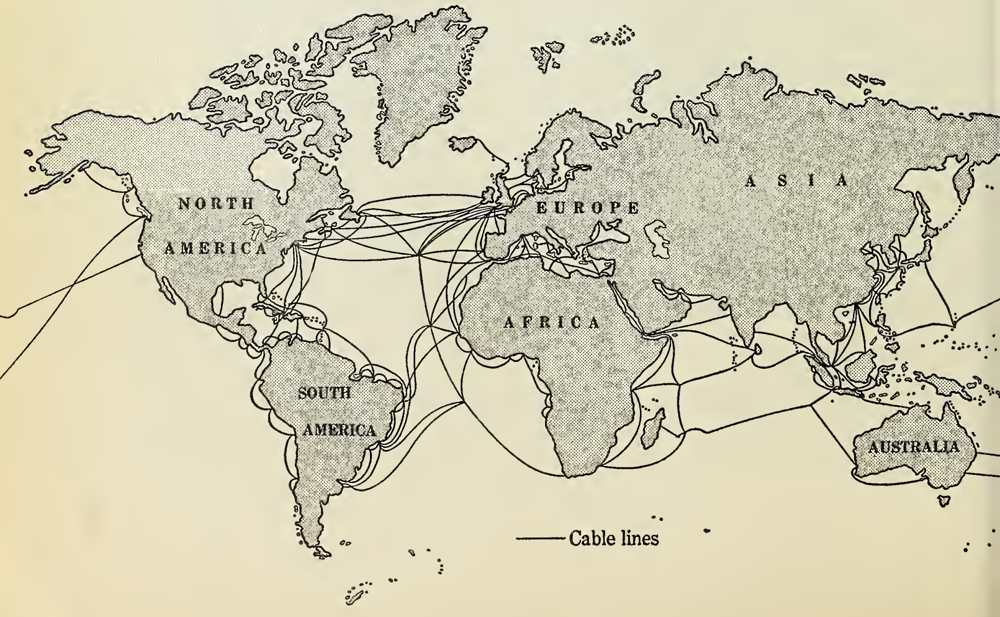
How We Hear Sound. One of the most obvious things about sound is that we hear it. Stretched across the opening leading into the ear is a delicate membrane known as the *eardrum.* Its position is shown in the diagram on the opposite page. The sound waves cause the drum to vibrate, and this motion is carried through a chain of small bones to the *inner ear.* This is a cavity filled with liquid, in which there are many nerve endings. The effect of the different vibrations on these nerve endings is interpreted by the brain in terms of the three properties of sound which we have studied in this section: pitch, loudness, and quality.

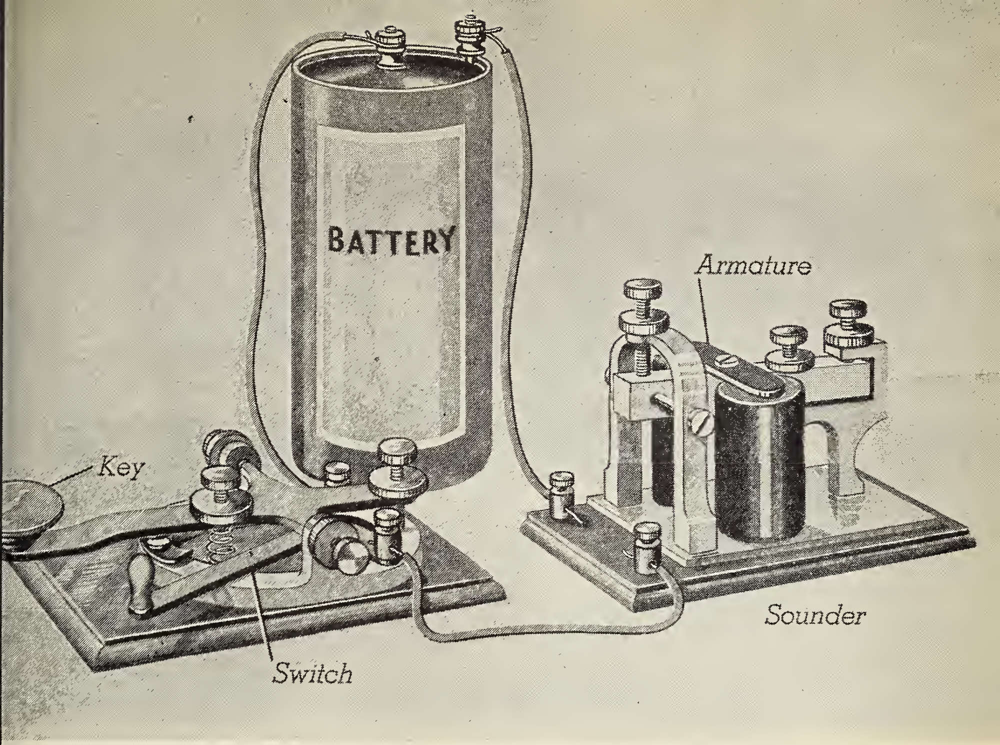
THE TELEGRAPH AND THE TELEPHONE

Sound and Electricity. Though sound has always been used as a means of communication among men, the use was very local until a way of combining sound and electricity was discovered. This was done by the invention of the telegraph, an instrument which enabled men at opposite ends of the earth to communicate quickly and clearly with one another.

The first telegraph line was built in 1844 between Baltimore and Washington, a distance of 40 miles, from directions furnished by Samuel Morse, the inventor. On May 24 of that year Morse sent the first telegram over that line, "What hath God wrought!" These words began a new era in communication. Seven years later a line from Washington to St. Louis, a distance of 1000 miles, was completed. This was considered a great achievement, but it was really only the beginning of a greater achievement. In 1927 over 2,000,000 miles of telegraph wire were in use in the United States alone. During that year 215,000,000 telegrams were sent.

Many cable lines tie the lands of the earth together

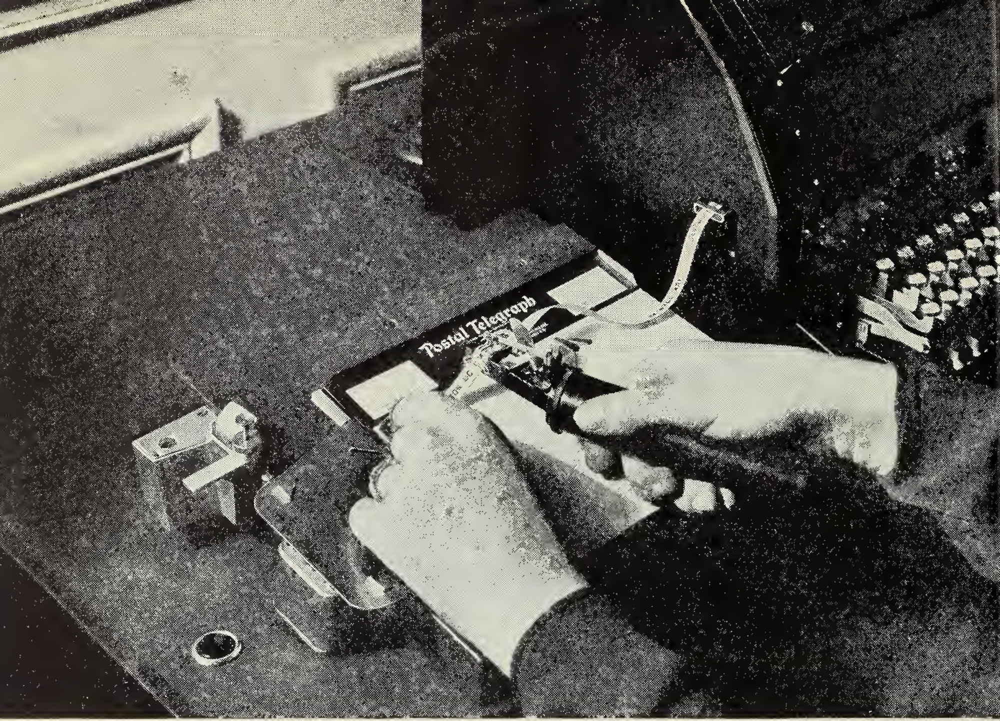




With this equipment you can learn how the telegraph works

A few years after the first telegraph line was built, telegraph cables were laid across the ocean. These cables consist of a copper wire wrapped with steel wire and rubber to protect and insulate it. The first successful cable was laid between Dover, England, and Calais, France, in 1851. The first successful cable across the Atlantic was laid in 1866. There are now nearly 400,000 miles of ocean cables in use, as shown in the diagram on the opposite page. The charges for the use of the first cable were about $100 per message. The present rate is about 25 cents per word.

How the Telegraph Works. The tremendous growth of the telegraph and cable was made possible by the discovery of the electromagnet, which you studied in the last chapter. A telegraph key and sounder are much like an electric bell, as the diagram above will show. In its simplest form



Postal Telegraph Cable Co.

The modern teletype machine both sends and receives messages

the *sounder* (or receiver) is an electromagnet with a bar (*armature*) mounted over it. When the *key* (or sender) is pressed, an electric current flows through the coils of the magnet in the sounder. The magnetic force draws the bar toward the poles of the magnet, and this produces a sharp clicking sound when the two meet.

When the key is released, the electric circuit is broken. The electromagnet in the sounder now loses its magnetism, and a spring pulls the bar away from the poles of the magnet. This causes the bar to strike the metal above it so that another click is produced. A short interval between the clicks as the bar moves down and up produces the effect called a *dot*. If there is a longer interval between the clicks, a *dash* is made. A trained telegrapher knows that dot-dash (. —) is the letter *A*. There are other combinations of dots and dashes to make the other letters.

Exercise. Get a simple telegraph key and a sounder, such as are used by the railroads today. Hook them up to a dry cell as shown on page 345 and study how each instrument operates.

The Teletype Machine. The first sending and receiving telegraph instruments were crude affairs compared with those in use today. The dot-dash instruments are now largely replaced by the teletype machine shown on the opposite page.

The message to be sent is typed on one of these machines. This process of typing operates a similar machine, having a keyboard like a typewriter, in the station to which the message is sent. As a message is typed in the sending station a duplicate copy is automatically typed on a strip of paper tape in the receiving station. In this way two operators, many miles apart, can type messages back and forth, each one seeing as fast as it is typed what the other writes.

Although much more complex than the simple telegraph instruments, these teletype machines also operate by means of electromagnets. Each letter on the receiving typewriter is operated by a separate electromagnet. When, for example, the sending operator presses the key for letter *A*, the key for letter *A* on the receiving typewriter is operated by its particular electromagnet so that that letter is printed. Such machines make it possible to send and receive messages at a speed much greater than that of even the most expert old-fashioned telegrapher.

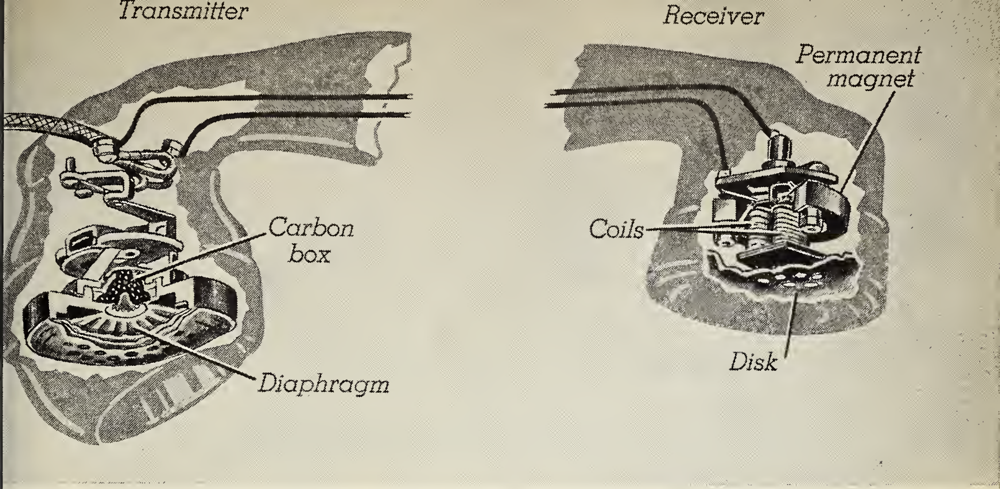
Teletype instruments may be made to set type for printing newspapers. It is now possible to type news on a teletype machine in New York City and have it set up, as it is typed, for printing in newspapers in England.

How the Telephone Was Invented. Some thirty years after the sending of the first telegram, another epoch-making message went over a wire. On June 2, 1875, in a small house in Boston, two men were at work on an electric circuit. One of them, Alexander Graham Bell, believed that the circuit could be used to carry the effects of sound waves, but so far the work had been unsuccessful.

The second man, Thomas A. Watson, had been quietly working alone in the attic. Suddenly he was disturbed by Bell, who rushed upstairs shouting, "What did you do then? Don't change anything. Let me see!" Watson explained that he had been tinkering with the transmitter, and Bell told him that he had heard the sound of the tinkering at the receiving end of the line downstairs. Further experiments were necessary, however, before the first telephone really worked. Finally, several months later, Watson heard Bell's voice over a telephone saying, "Mr. Watson, please come here; I want you."

From then on progress was rapid, though not easy. Difficulties about money delayed Bell and his helper, but finally these difficulties were overcome and commercial development began. By 1880 there were over fifty thousand telephones in the United States; by 1900 there were close to two million; and by 1910, there were more than six million. Today the telephone is in almost every home of civilized man.

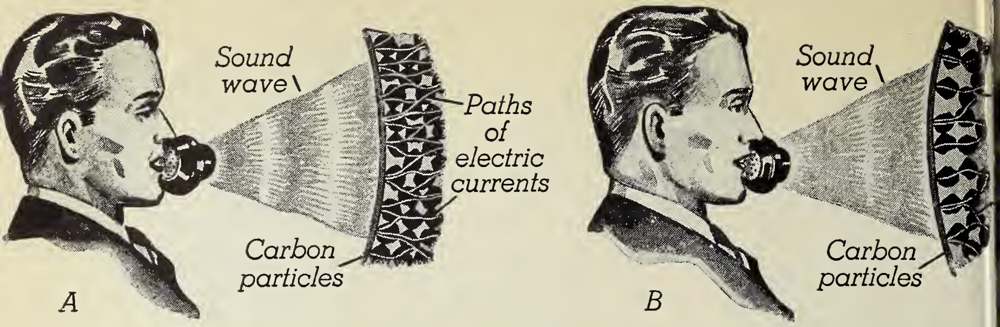
The telephone has changed in appearance but not in principle since its inventor sent this first long-distance message



se diagrams show the construction of the modern telephone transmitter and receiver

How Sound Waves Affect the Flow of Electricity. A diagram of a modern telephone *transmitter* is shown above. Behind the mouthpiece of such an instrument is a metal disk, or *diaphragm*. When you speak into a telephone, the sound waves cause the diaphragm to vibrate. If you have examined the diaphragm of a telephone transmitter, you have seen a metal stud, or nail, through the center of it. This stud fastens the diaphragm to one side of a small box which is filled with grains of carbon. Wires attached to this *carbon box* are connected to some source of electric current.

When sound waves strike the diaphragm of a telephone transmitter and make it vibrate, the carbon particles are first pressed closer together and then released. The drawings on page 350 show what happens over and over again as the diaphragm moves back and forth against the little grains of carbon. When the diaphragm is pressed in and the particles of carbon are squeezed tightly together, there are more paths along which an electric current can travel. When the diaphragm is bulged out and the particles of carbon are more loosely arranged, there are fewer paths along which an electric current can travel.

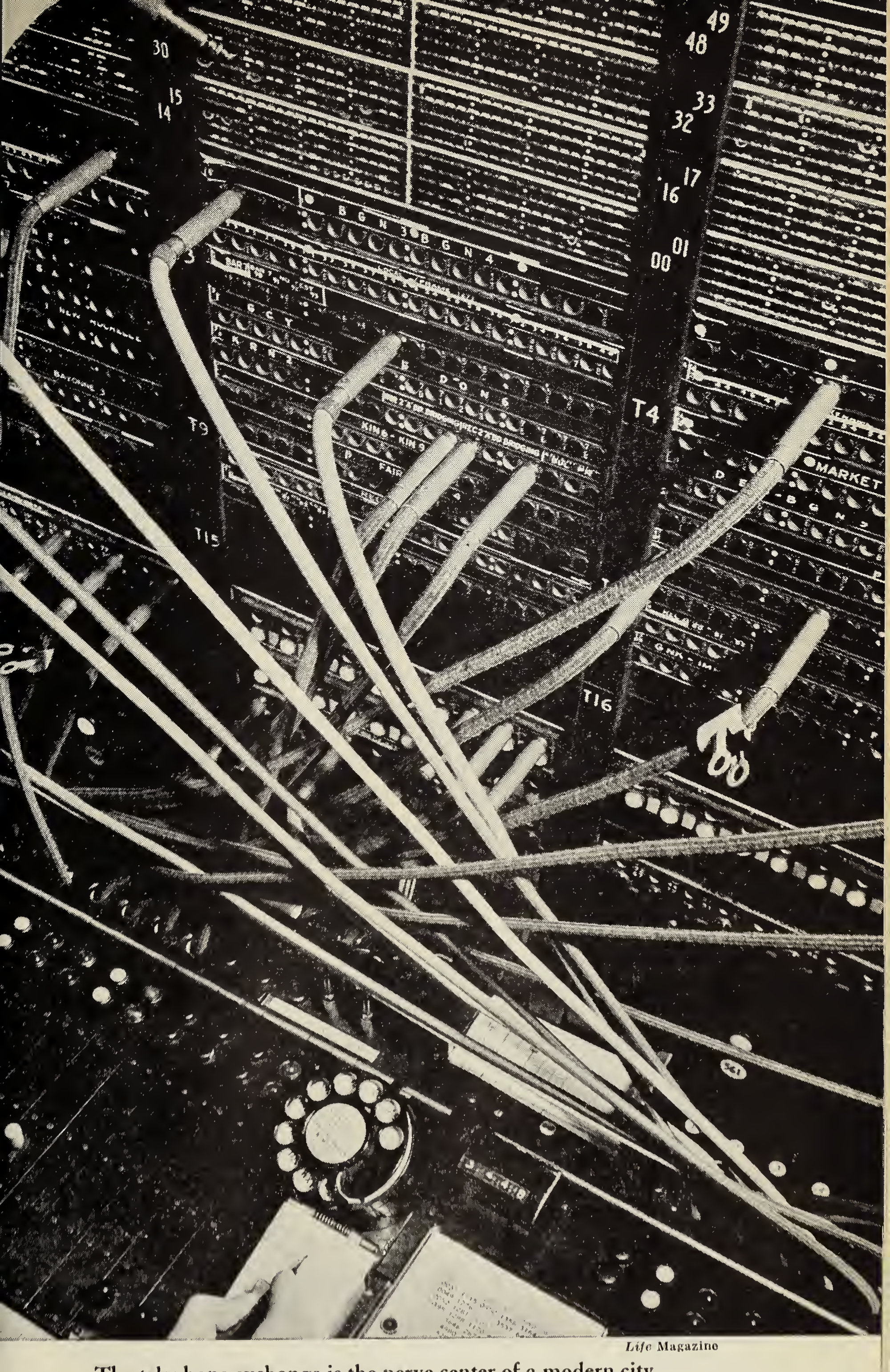


When the diaphragm is pressed against the carbon particles in a telephone transm
(A), there are many paths along which electricity can travel. When the diaphrag
bulged out (B), the carbon particles spread apart and reduce the number of path

In other words, when the particles of carbon are squeezed tightly together, the resistance to the flow of electricity is reduced; when the particles are more loosely arranged the resistance to the flow of electricity is increased. Do you see, then, that sound waves striking the diaphragm cause a current of first stronger and then weaker electric energy to move through the carbon box?

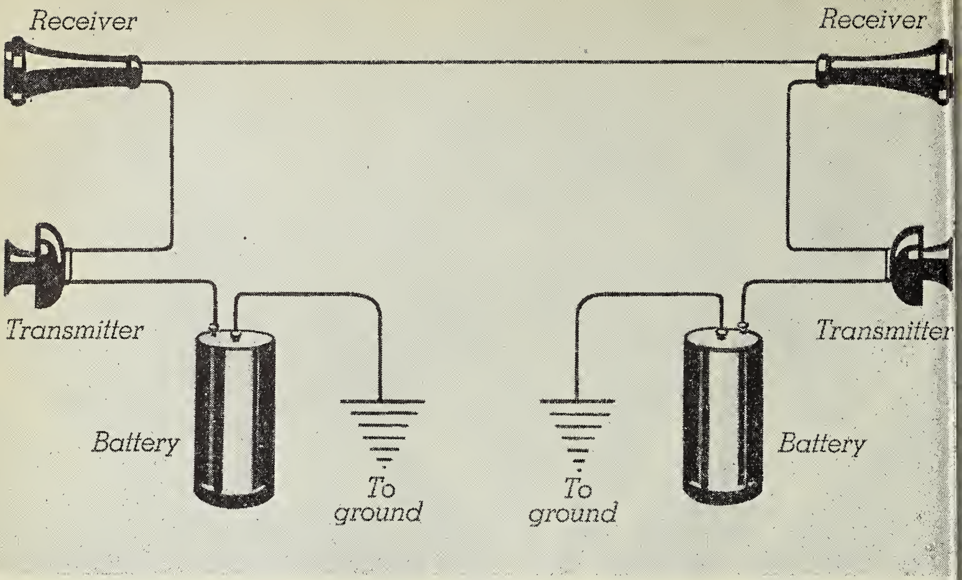
What Happens in a Telephone Receiver. The business of a telephone transmitter is to turn sound waves that come from the voice into an irregular, or *pulsating*, *current* of electricity. The business of a telephone receiver, such as is shown on page 349, is to turn the pulsating current which comes from the transmitter back into sound waves. If you have ever examined the inside of a telephone receiver, you have discovered a metal disk similar to the diaphragm of the transmitter. Underneath the disk is a small horseshoe magnet, a permanent magnet which gently attracts the disk at all times. Notice, however, that inside the horseshoe magnet are the coils of two electromagnets which exert an additional pull on the disk when an electric current passes through the wire. It is these electromagnets that receive the pulsating current from the transmitter.

The disk of the receiver is supported in such a way as never to be quite able to touch the ends of the electro-



Life Magazine

The telephone exchange is the nerve center of a modern city



If you want to rig up a private telephone line between your house and the house of the boy next door, this is the way to d

magnets. When the current grows strong, the magnetism in the electromagnets also grows strong, and the disk is pulled inward. When the current grows weak the magnetism also grows weak, and the disk snaps outward. So it is that the disk in the receiver is made to vibrate many times a second, to correspond to the vibrations which are set up in the transmitter.

The result is that the air near the disk is also made to vibrate so that sound waves are set up in the receiver that are similar to those that strike the diaphragm of the transmitter. You *seem to hear* these sound waves as the voice of the person at the other end of the line. What you really hear is a *copy of the voice* of the speaker, made possible by exact reproduction of its effects through vibrating pieces of metal.

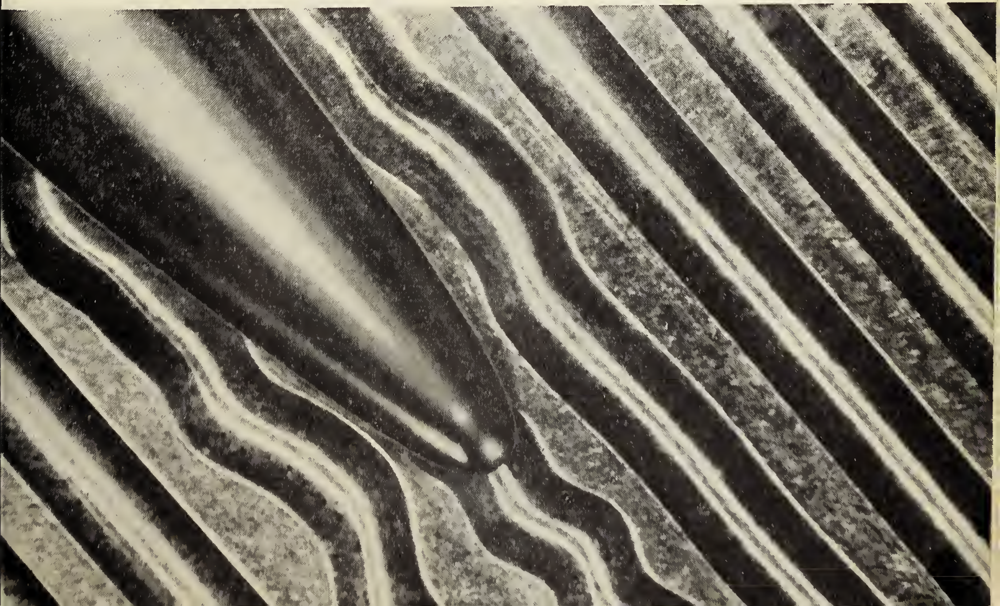
Telephone Circuits. The simplest kind of telephone system is that shown at the top of this page. Though still used in some rural districts, this "hookup" is not practical for cities or for long-distance service. If you have ever visited a telephone exchange such as is shown on page 351, you know that modern telephone service is a complicated business. Thousands of telephones strung together with thousands of miles of wire make many special problems which are beyond the field of this book.

The loss of electricity from telephone wires is one of the chief problems. It is partly overcome by *transformers*, which increase, or "step up," the voltage of the electric current. The "stepping up" process makes it possible to carry the effects of the human voice around the world. If later you take a course in physics, you will probably learn in detail about the complicated instruments that have made it possible to carry electric energy through so vast a distance.

Exercise. See if you can arrange a sight-seeing trip for your class through a telephone exchange in your vicinity. Take notes on what you see and are told, and make them into a report after you have returned home.

is highly magnified phonograph needle made these wavy grooves in a wax record while recording the music of a band

RCA Manufacturing Co., Inc.



THE PHONOGRAPH AND THE RADIO

How Phonograph Records Are Made. The telephone is not the only instrument that makes use of the fact that sound is the result of vibration. Every time you play a phonograph you make use of the same principle.

How is sound recorded on a phonograph record? Let us say that a dance band is making one of the popular recordings of the day. In a studio that somewhat resembles a radio broadcasting studio, the sound of the music enters a horn or other device for gathering sound. The sound waves then strike a diaphragm which vibrates in the manner of the diaphragm of a telephone transmitter.

The blunt end of a needle is attached to the diaphragm, its sharp end resting on a soft rotating wax disk. As the diaphragm vibrates, the needle vibrates. The vibrations of the sound waves produced by the players are thus carried to the needle, and the needle in turn digs a wavy groove in the wax of the spinning disk. Notice the highly magnified track of such a needle, as pictured on page 353. This track is a record of the vibrations produced by the music of the band.

With time it was discovered that more faithful recording of sound is possible if the vibrations of the diaphragm are carried to the recording needle by electricity. All modern *electrical recording* is therefore done by this method. When the

This man is getting ready to make a phonograph record by pressing hard rubber between two copper master records

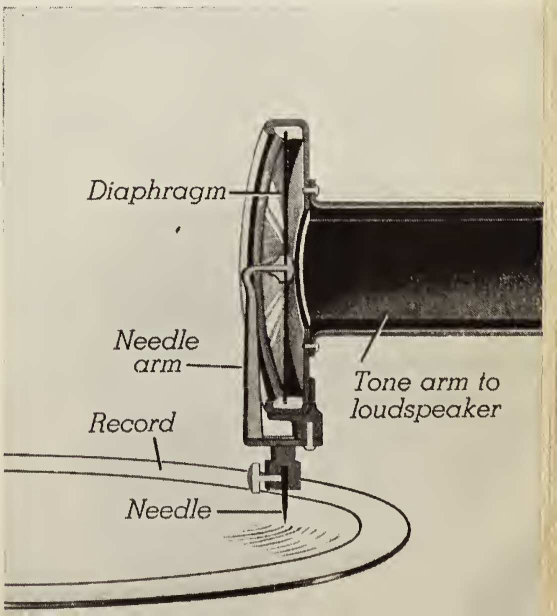
wax record is finished, an exact copy of it (a *master record*) is made in copper by the process of electroplating which you studied in Chapter Five. The record you buy in a music store is made by pressing hard rubber against the master record until the grooves of the original recording are faithfully impressed upon it.

How Phonograph Records Reproduce Sound. When you play a phonograph record, you merely turn the sound vibrations recorded in the grooves into sound again. A simple experiment will show you how this is done.

Exercise. "Play" a phonograph record with a needle held in your hand. Can you feel the needle vibrate? Can you hear the record playing softly?

The mechanical "pickup" shown below is a better instrument than your hand for picking up the vibrations from the grooves of a record. Notice that the needle is connected to a diaphragm which vibrates when the needle moves along the grooves of the record. The vibrations are turned into sound waves which come to your ear from the sound chamber of the phonograph. In electrical phonographs the vibrations are first strengthened (amplified) by electricity, and then changed to sound waves with the help of an electromagnet and diaphragm.

The "pickup" of a record-player turns into sound the vibrations "picked up" from the grooves of a record



The Wireless Telegraph. Thomas A. Edison invented the phonograph in 1876, the same year that a human voice was first heard over a telephone. Twenty years later, in 1896, an even greater triumph of communication was achieved. Guglielmo Marconi, a young Italian scientist, sent a telegraph message a distance of two miles *without the help of wires.*

Not until December 12, 1901, however, did the first great demonstration of wireless telegraphy take place. On that day in a small room at Saint John's, Newfoundland, Marconi sat with a crude set of headphones clamped over his ears. Outside a storm was howling. After much effort a kite had been raised, and attached to it was a wire (*aerial*) connected with a receiving instrument in the room.

Marconi listened eagerly. Suddenly he pressed the headphones to his ears. From Cornwall, England, came the sound of three dots on a telegraph sounder, the letter *s* in the Morse code. The first wireless message had crossed the Atlantic Ocean.

Think of the progress that has been made since that historic day. Your parents can probably remember when wireless, crude though it was, was an almost unbelievable wonder. Today by merely twisting a dial you can get music and speeches by wireless from all over the world. The radio is merely Marconi's invention in modern dress.

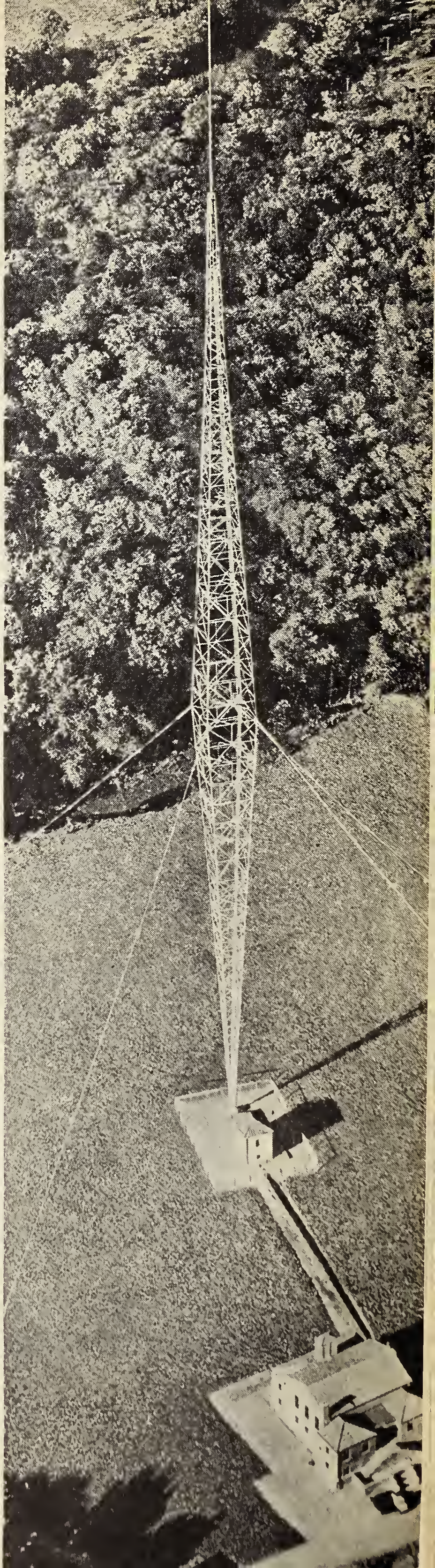
The radio offers a field of great interest to the amateur electrician

Los Angeles Schools

Radio Waves. Of all electrical instruments the radio seems to many people the most difficult to understand. The operation of a nine-tube or an eleven-tube radio is indeed complex. There are tubes and coils and wires of many kinds. Yet when this mass of mechanism is attached to an aerial and plugged into an electric-light circuit, merely the turning of a dial brings in programs from all over the world.

The principles on which a radio works are not so complex as the instruments through which they work. Some of these principles are already familiar to you from your earlier studies in this unit. You already know that radiation is a form of energy and that there are several types of this radiant energy. Light and heat are types which you have studied in some detail. Radio waves are another type.

The Radio Transmitter. Unlike light and heat waves, radio waves cannot be sensed by the human body. They may be detected only through the use of instruments. Progress in



Columbia Broadcasting System

Rapidly alternating currents of electricity run up and down the tower of a radio transmitter

the development of radio has been progress in developing instruments for sending and receiving these mysterious waves.

These instruments consist in general of two essential parts: the *transmitter* and the *receiver.* The transmitter in the broadcasting station develops and sends out the radio waves. A rapidly alternating current of electricity is caused to flow back and forth in an aerial, which may be a wire but is usually a tower such as is pictured on page 357. As the electric current moves up and down in the aerial, the radio waves develop and are sent out in all directions. Like waves of light, these radio waves travel at a speed of about 186,000 miles per second.

Inside the broadcasting station the sound of the program is directed into a *microphone,* which operates on the principle of a telephone transmitter. The vibrations in the microphone are changed into a pulsating electric current just as in a telephone. Through several very complicated instruments, the radio waves which are going out from the aerial are made to vary in strength to correspond with the pulsations in the current from the microphone.

The Radio Receiver. The alternating electric current which runs up and down the aerial of any given transmitter moves at a definite speed, or *frequency.* If, for example, the current is moving up and down at the rate of 500,000 times a second, the station is said to be operating on a frequency of 500,000 *cycles,* or 500 *kilocycles.* ("Kilo," you remember, means "one thousand.") The radio waves set up by this current go out from the aerial at the same frequency.

In order to listen to the programs from any given station you must "tune in" your receiving set to the frequency of the sending station. By turning the dial you change the frequency to which your set is sensitive. When your receiver is properly "tuned in," the radio waves from the transmitter strike your aerial. They cause a weak alternating current of electricity to flow back and forth at the same frequency with which the alternating current flows in the aerial of the sending station.

Inside your radio cabinet the current from the aerial passes through "tubes" which strengthen it with the help of electric energy from the house circuit. The rapidly alternating current from the aerial is then changed into a pulsating electric current by a variety of complicated instruments. Finally, the pulsating current is amplified until it can operate the electromagnet in a loud-speaker. This instrument works much in the fashion of a telephone receiver. It contains a diaphragm that sends out sound waves to the ears of a listener. These sound waves are a copy of the sound waves that go into the microphone of the transmitter.

Television. Already the radio has slipped into the class of familiar things. Television is the new wonder of communication. Like radio, television makes use of radio waves, but light waves instead of sound waves must be used to control the strength of the current that moves through the aerial.

Because only very short radio waves can be used to broadcast images, television reception is possible at present only within a few miles of the sending station. The entertainment that the people in the picture on page 360 are enjoying may now be had only in a few large cities. But as in the case of the telegraph, the telephone, the phonograph, and the radio, great improvement will surely come. Man,

National Broadcasting Co.

Television is the new wonder of communication

indeed, will doubtless continue to increase his powers of communication in many ways—but in ways that no one can definitely predict.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The difference between a low note and a high note on a piano is that the high note is the result of fewer vibrations per second.
2. The faster a body vibrates the louder will be the sound it makes.
3. The property of sound that makes one tone more pleasant to the ear than another tone is called pitch.
4. Sound travels 1100 feet per minute, which is much more slowly than light travels.

5. The inner ear is a membrane that vibrates when sound strikes it.

6. Sound waves, like water waves, travel only over smooth surfaces.

7. The telegraph was the first instrument in which sound waves were used to affect the flow of an electric current.

8. The teletype machine is an improvement over the old-fashioned key and sounder because it does away with the need for electromagnets.

9. In a telephone transmitter, an electromagnet is used to change sound waves into an electric current.

10. A pulsating current is one that moves back and forth in a wire with great rapidity.

11. Sound waves pass over a telephone line with the speed of light.

12. When a phonograph record is described as an "electrical recording," it means that the master record was made by the process of electroplating.

13. The aerial of a radio station is always a wire lifted high in the air.

14. A radio wave is the current of electricity that moves through the coil of an electromagnet.

15. The frequency of a radio broadcasting station depends on the number of hours the station operates each day.

Questions for Discussion

1. Can you think of any things which might influence the quality of sound?

2. Would you agree that the telephone is a necessity rather than a luxury in our modern civilization?

3. What evidence can you present on both sides of this question, "Is radio a blessing or a curse in modern life?"

4. In England radio listeners are taxed for their sets, and the money thus secured pays for the cost of programs. In this country the cost, for the most part, is paid for by advertising. Which method do you think is better?

Things to Do

1. Musicians group musical instruments into these general classes: the percussion group, the wind group, and the string group. Find out what kind of instruments each of these groups contains. Does vibration enter into the production of sound by the instruments in each of these groups? Does it differ from group to group?

2. Set up a telegraph line between your house and a neighbor's. If you cannot afford to buy keys and sounders, your town librarian can probably help you to find directions for making these instruments cheaply. Once your telegraph line is set up you can soon learn how to send messages by the Morse code.

3. If you have never made a tin-can telephone, you might enjoy doing so now. Fasten the ends of a wire tightly into the bottoms of two tin cans. The easiest way of doing this is to make holes in the middle of the bottoms of the cans, pull the ends of the wire through, and then knot them so they cannot pull out. If the wire is then drawn tight, the bottom of the can at one end will vibrate when you talk into it. The vibrations will travel over the wire so that a person with his ear to the can at the other end will hear what you are saying. This telephone will work between your house and your neighbor's, but not for a much greater distance.

4. Plan to take a trip to a radio broadcasting station. Be sure to decide just what you want to find out and the questions you want to ask, so that your trip will not be merely a sight-seeing one.

CHAPTER THIRTEEN

How Do We Get About?

PRIMITIVE METHODS OF TRANSPORTATION

The Importance of Getting About. Life for us would be quite impossible if we were forever anchored to one spot. Unlike trees, which are rooted in the ground, we cannot make food in our own bodies from the air and soil that surround us. Unlike sponges, which are rooted in the floor of the sea, we cannot just sit and wait for some friendly current to wash food into our mouths. We must hustle for a living, and thereby hangs a tale.

It is the tale of how men have mastered space through the art of transportation. Ever since men first came to live on the earth they have been moving themselves and their possessions from one place to another. The history of civilization is in large measure the history of this moving about, the history of transportation. Since much of the energy which we control today is used in this great division of human activity, it is only fitting that we close this unit on energy with a study of transportation.

The First Beasts of Burden. Before human beings learned how to raise cultivated plants for food, they wandered about like animals in search of whatever wild food the earth might offer. In the very beginning they probably had no domesticated animals to pull them from place to place. They moved with the energy of their own muscles.

This does not mean that primitive tribes in search of new hunting grounds had no carriers of the simple household equipment that even very ancient people must have

Byrd Antarctic Expedition II

Cross-country travel in frozen lands depends largely upon the dog

possessed. There is good reason to believe that the women carried the heavy loads. While the men wandered ahead with their weapons in search of game the women no doubt brought up the rear with the baggage.

Use of Animals in Transportation. Though women still serve as beasts of burden among some backward peoples of today, animals were early pressed into the service of transportation. Nobody knows exactly what animal was first domesticated by man, but the dog is a likely candidate for this distinction. Perhaps dogs were also the first animals to pull loads for men, though their small size partly unfits them for this purpose.

In frozen lands, however, where loads can be moved easily on sleds, dogs are extremely useful in transportation.

They can be taught to work well together, and they move easily over the uncertain surface of ice and snow. Most of all, they seem to like it. Transportation in the Far North, even today, depends to a large extent on the dog team.

Several other kinds of animals have served as beasts of burden since a time that is buried in the mists of the past. Oxen and their relatives, the yak and the buffalo, have perhaps been the most widely used beasts of burden for the longest period of time. They have spread to all the continents of the earth and are still used not only for pulling wagons and plows but also for food.

Special places very early developed their own special beasts of burden. In India the elephant was trained to carry heavy logs and to break trails through the jungle. In South America the little llama was trained to carry small burdens over the breath-taking heights of the Andes. In Africa the camel, large cousin of the llama, has long been

Oxen still do a part of the world's work

Harold Orne

used for transportation on the trackless wastes of the Sahara. In northern lands the reindeer has long been doing the work that the horse has done farther south.

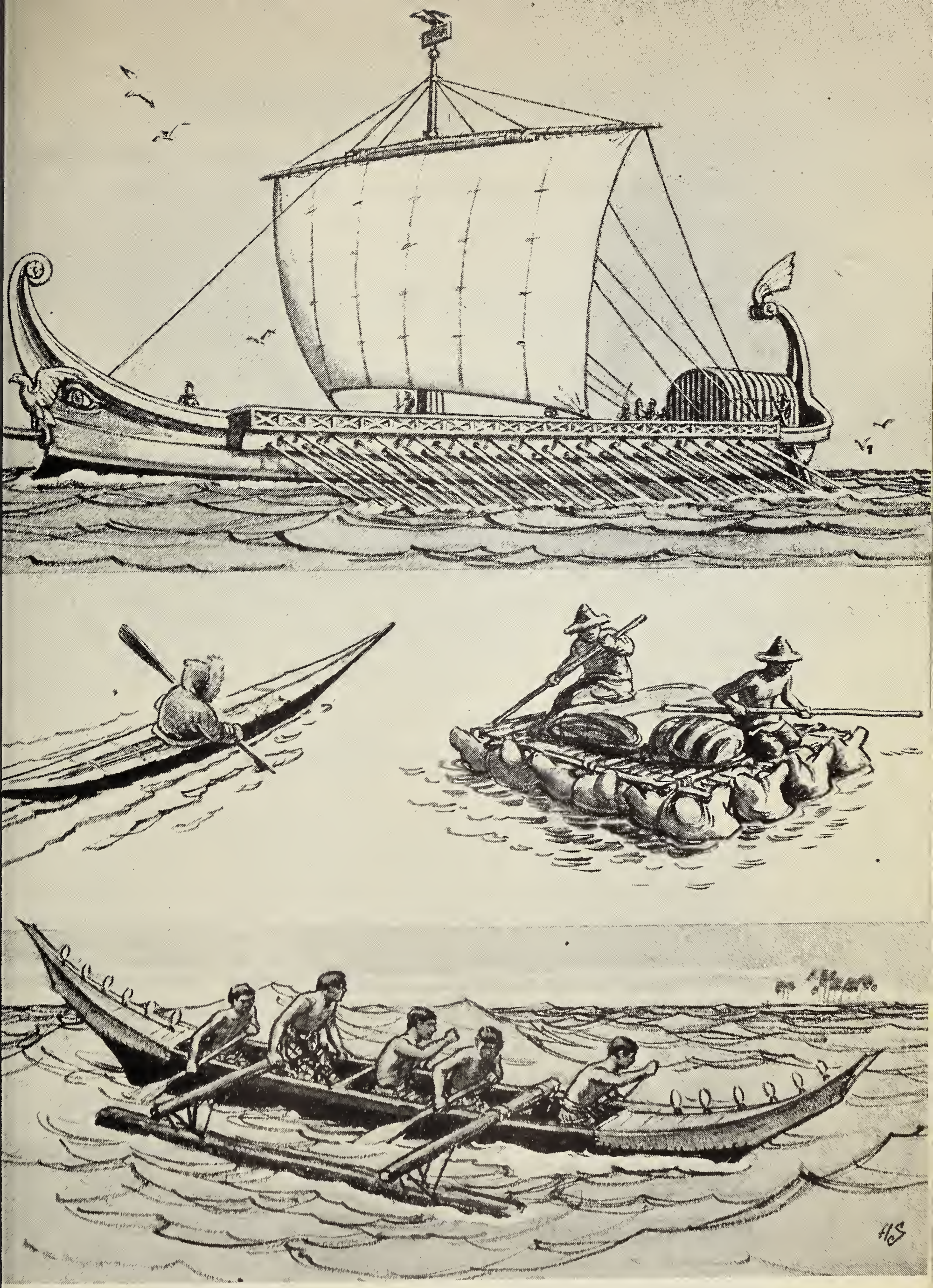
Exercise. Look up the history of the horse as a beast of burden and report on it in class.

Early Transportation by Water. Primitive men must very soon have discovered that it was easier to move over water than land. The smooth surfaces of streams and lakes must early have been a challenge to human invention. The first crude boat was probably a raft such as you yourself have doubtless made. We know that the early Egyptians used rafts of logs and grass on the Nile. We know that the early Incas used similar rafts on Lake Titicaca, in the high Andes.

Nobody knows what people invented the first real boat. It was not a long step, however, from a raft which was pushed along by a pole to a canoe which was pushed along by a paddle. Primitive types of boats are still in use in many places. Skins blown up with air are still used on the Yellow River of China to support rafts, as you may see in the illustration on the opposite page. Such use of skins might easily have led to the invention of a true skin boat, as pictured on the same page.

Long before civilization may be thought to have really begun, a variety of simple boats were doubtless moving about on the inland waters of the earth. Boats made of solid logs, dug out to carry passengers and loads over water, are still in use. The birchbark canoe of the American Indian was the father of a means of transportation that is still widely used on the vast network of lakes and streams of northern North America.

Among the finest of all primitive craft were the seagoing boats of the Polynesian people of the South Pacific islands.



fts floated on air-filled skins (center right) are still in use on the Yellow River of ina. The sealskin kayak (center left) may still be seen in Alaska, and the dugout oe (bottom) in the South Sea Islands. The Roman galley (top), most handsome of all primitive boats, has completely disappeared

On page 367 is a drawing of one of these boats. Such vessels are still widely used to carry men and goods from island to island across many miles of ocean.

Exercise. Look up the history of the canoe in the exploration of North America and report on it in class.

DEVELOPMENT OF WATER TRANSPORTATION

From Muscle to Wind. In driving his boat through the water with a paddle, primitive man made use of a simple machine. He did not know (as you who have studied Chapter Eight of this book know) that the paddle is a lever of the third class. When he fixed the paddle to the side of the boat and used it as an oar, he did not know that he was making use of a lever of the second class. What he did know was that he could make his boat move through the water more easily by paddling than by poling, and still more easily by rowing.

The rowboats of early times were handsome affairs, as you may see from the picture on page 367. By means of these many-oared boats, the ancient peoples of the Mediterranean region were able to establish and direct the affairs of colonies which lay many miles from home. Through these boats, no less than through its fine roads, the vast Roman Empire was held together for centuries.

The Reign of the Sailing Vessel. Just when it was that someone thought of putting a sail on one of these mighty rowboats, nobody knows. That day was nevertheless an important one in the history of navigation. It marked the dawn of the long era in the history of water transportation when wind rather than muscle supplied the driving force.

As time went on, men ventured farther and farther from home in wind-driven ships. The romantic stories of Columbus and other pioneer mariners of the fourteenth, fifteenth, and sixteenth centuries need no retelling here. It was these men who really discovered the earth and who tied it together with the bonds of a common culture. The sailing vessel was their most important tool. Without its help civilization as we know it would never have spread beyond Europe.

Dawn of the Steamship Era. Even the most glorious of ages must sometime come to an end. Though sailing vessels were still aiding in the discovery and colonization of new lands in the nineteenth century, their day was drawing to a close. A new era was born when, in 1807, Fulton drove his famous *Clermont* up the Hudson River with the energy of steam.

Fulton's steamboat was the grandchild of Watt's steam engine, which we studied in Chapter Nine. The steam engine had already been made to run a variety of machines, including a crude little passenger boat which John Fitch operated on the Delaware River as early as 1786. No steamboat, however, was really successful until Fulton built the *Clermont*. This boat, pictured on page 370, was 130 feet long and driven by a paddle wheel at the side. When it ran from New York to Albany on its first voyage, a distance of 150 miles, in 32 hours, the world knew that the steamboat had proved its worth. It knew that navigation was at last free from the fickle whims of the wind.

Exercise. Look up in the library accounts of Fulton's *Clermont*. Also look up accounts of the steamboats that were invented before the *Clermont*. Make a report to your class describing these boats and pointing out why they were inferior to the *Clermont*.

The Development of the Steamboat. A mere century and a quarter separates the slow little wooden *Clermont* from the great fast steel steamboats of today. The *Normandie*, pictured on the opposite page, is nevertheless just as much the grandchild of the *Clermont* as the *Clermont* was the grandchild of Watt's engine. The development from one to the other was a natural process.

Certain red-letter days mark the history of this development. The first steamboats, like the first sailing vessels, did not dare to venture into the open ocean. Gradually boats equipped with both sails and steam power ranged

The steamship era was born when Fulton's Clermont ran up the Hudson on its own po

From a painting by Henry O. Ogden, courtesy New York Historical Society

H. Armstrong Roberts

The Normandie is one of the great triumphs of the steamship era

farther and farther from land. Finally, in 1833, the *Royal William* crossed the Atlantic wholly through the power of steam.

From then on bigger and better steamboats appeared as a matter of course. The first screw propeller, invented in 1836, predicted the end of the paddle wheel. The first iron hull, invented a few years later, predicted the end of small wooden ships and the coming of large steel ones. With these improvements in the body of the steamboat came parallel improvements in the engine. Ships became ever faster and more comfortable. A century ago a trip to Europe meant at least a month of uncertainty and comparative hardship in a sailing vessel. Today it means five days amid the luxuries of a fine hotel.

Why Metal Boats Float. When you look at a great modern steamship made largely of metal, you may well ask the question, "How can this giant float?" You know that a chunk of iron or steel rapidly sinks in water. Why doesn't an iron ship also sink? The answer is that if metal ships are built in accordance with the law of buoyancy they will float as readily as wooden ones. But what is the law of buoyancy?

Perhaps you have lifted a heavy stone from the bottom of a stream or lake. When you got it to the top of the water and tried to move it farther, you discovered that it seemed heavier. The reason for this was that the water helped to support the stone while it was in the water. We call this supporting force of water *buoyancy.*

Exercise. How to measure buoyancy: Tie a piece of string round a stone and attach the other end of the string to a spring scale. How much does the stone weigh? Now lower the stone, still attached to the scale, into a pail of water. Does the scale register the same weight as it did before, or is part of the weight of the stone supported by the water?

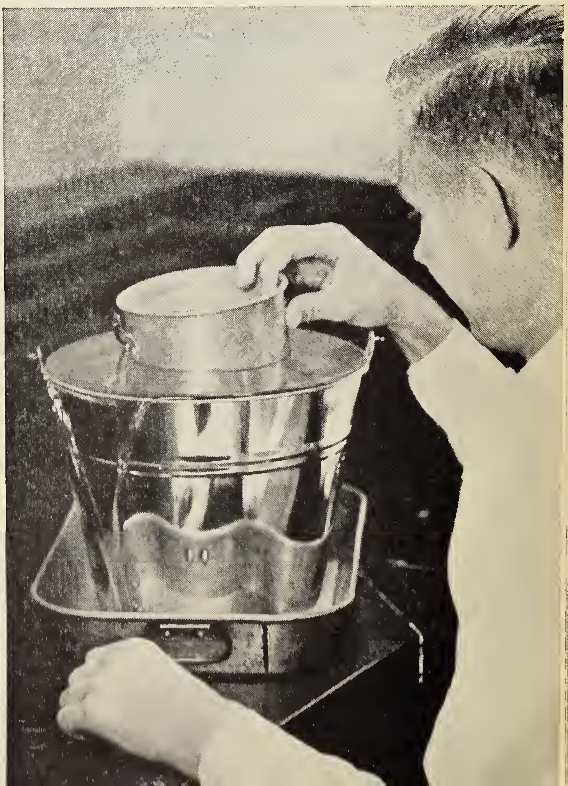
Over two thousand years ago a Greek scientist named Archimedes made careful studies on buoyancy. He came to the conclusion that *any body placed in a liquid is buoyed up by a force which is equal to the weight of the liquid displaced.* Let us see exactly what this means. The stone which you put in water in the above experiment had to make room for itself in the water by pushing aside, or displacing, an amount of water that was equal to its own volume. This displaced volume of water weighed a certain amount. It was this amount which buoyed up your stone and which you measured with the scale.

The amount of water displaced by the stone weighed *less* than the stone itself. That is why the stone sank, even though it was made to appear somewhat lighter by the buoyancy of the water. If you had used a dry wooden stick instead of the stone, the stick would have floated because the water it displaced would have weighed *more* than the stick itself.

Do you see then that an object will float only when it weighs less than the liquid it displaces? It does not matter what an object is made of so long as its shape is such that it will displace an amount of water which is greater than its own weight. If metal objects are correctly shaped, they will float as readily as wooden objects, as you can prove in a simple experiment.

Exercises. For this experiment you will need a small pan, a bucket, and a large pan, as pictured at the right. First weigh the large pan, then the small one. Fill the bucket with water and place it in the large pan. Now float the small pan on the water in the bucket as if it were a small empty metal ship. You will see that some of the water is displaced and runs over into the large pan. Lift the bucket from the large pan and, without spilling any water, weigh the large pan with the water in it. If you subtract the weight of the

This boy is studying the buoyancy of a metal object



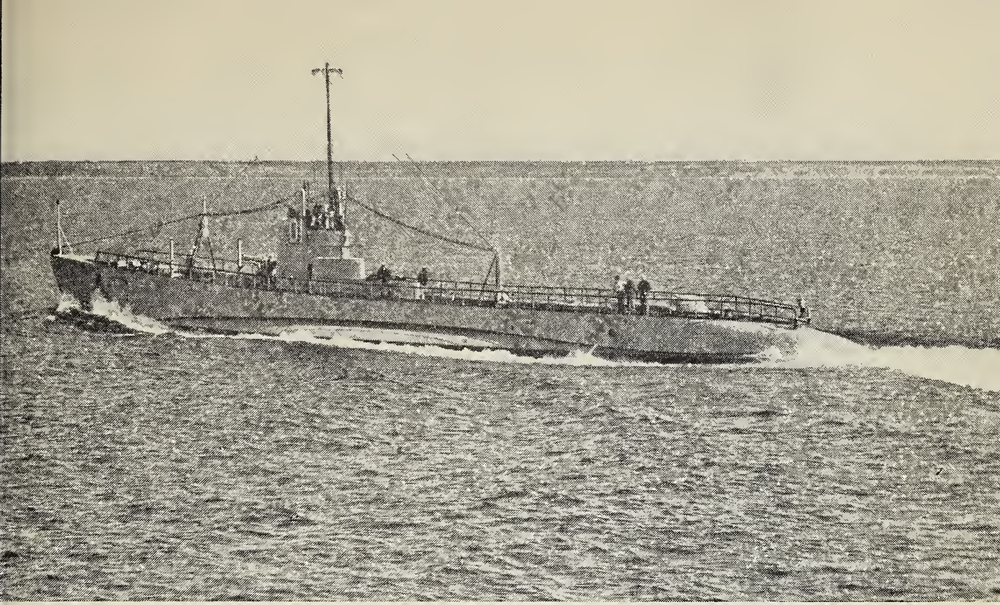
empty large pan from the weight of the large pan with the water in it, you may see how much water ran over. How does the weight of the water that ran over compare with the weight of the small pan that you floated in the bucket?

Next, place a cargo of stones or nails in the small pan until it reaches the point where it is in danger of sinking. Does the pan displace more or less water than it did when empty? Does the displaced water weigh more or less than the pan and its cargo? About how much can the pan and cargo weigh with reference to the water they displace before they sink?

There is a great difference, of course, between the small pan in the above experiment and a great ocean liner. You may think that a modern ocean liner must surely be heavier than the water it displaces. But if you have ever examined a large ship, you know that it is not a solid mass of iron or steel. As you go down and down from one level to another, you find that there is much open space between the decks. This space is filled with air, which is much lighter than the same volume of water.

If this air is replaced with cargo, or if water gets in over the side or through a hole, the total weight of the ship will be greatly increased. If enough water gets in or enough cargo is taken on so that the whole ship weighs more than the water it displaces, it sinks.

How Submarines Work. Submarines, like surface boats, operate according to Archimedes' principle of buoyancy. Every submarine must be equipped with large *ballast tanks*, which in some cases run the whole length of the boat. When the submarine is on the surface, these ballast tanks are filled with air. When the submarine is ready to go down,



Keystone-Underwood

aking water into its ballast tanks a submarine can sink below the surface of the sea. By pumping out the water it can return to the surface

water is let into the tanks. The weight of the water increases the weight of the submarine, and it sinks. By increasing or decreasing the amount of water in the ballast tanks, the submarine can be made to go deeper or to come to the surface.

How deep may a submarine dive? The present record is close to 400 feet. "Why can't it go deeper?" you may ask. The answer lies in the tremendous pressure of the water at great depths. A cubic foot of water weighs about 62 pounds. At a depth of 400 feet the pressure on each square foot of a submarine is nearly 25,000 pounds. This is more than 170 pounds on each square inch.

Remember that in order to go down the ballast tanks of the submarine are partially filled with water. In order to rise again this water must be forced out of the tanks by means of pumps. These pumps must be powerful enough to force out the water against the pressure of the water outside. The best pumps now in use are not strong enough to overcome a pressure of much more than 170 pounds per square inch. So if a submarine went lower than 400 feet with pumps of this strength, it could not return to the surface.

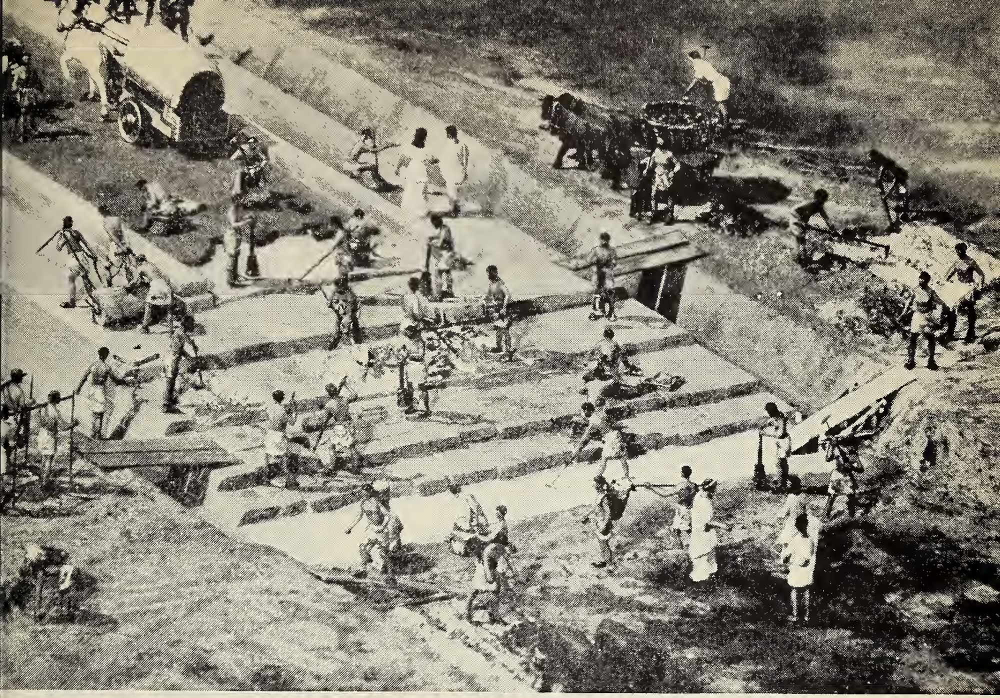
Exercise. Read Commander Ellsberg's *On the Bottom.* This is a really exciting story about the work of the deep-sea diver and the dangers of life in a submarine.

End of the Steamship Era. Though we are now at the height of the steamship era, we are probably also at its end. The steady improvement of the steam-driven vessel has brought it to the stage where it is no longer driven by steam. Boilers for steam engines and turbines take up much room, especially on large powerful ships. The Diesel engine, which we have already studied, takes up much less room and is much less expensive to operate. Many ships are already using these engines in place of steam engines. The steam-driven vessel is as surely doomed as was the wind-driven vessel before it.

DEVELOPMENT OF LAND AND AIR TRANSPORTATION

Ancient Roadways. While transportation on water was developing with time, transportation on land was not lagging behind. The earliest known civilizations in Europe, Africa, and Central America had roads. If you ever go to Rome, you can have the strange pleasure of driving in an automobile over the Appian Way, a very fine road that was first built more than 300 years before Christ was born.

With the fall of the Roman Empire road-building all but ceased in Europe. People organized themselves in small local groups rather than in vast empires. Not until the



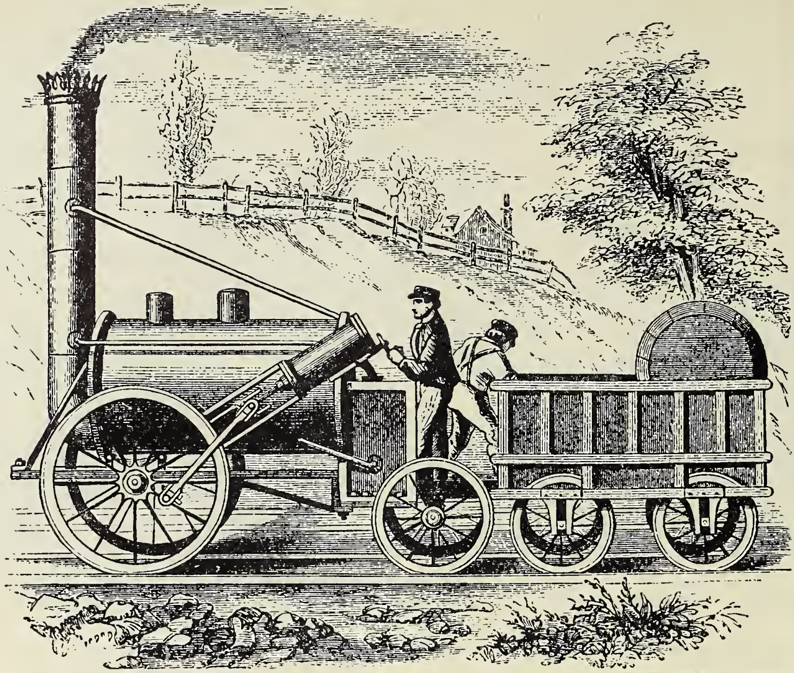
Smithsonian Institution

ng before the birth of Christ the Romans knew how to build roads that would last

sixteenth century was almost over did road-building become popular again. Then in France a national system of stone-covered highways was begun.

The Era of the Steam Railway. Since then the progress of land transportation has been uninterrupted. The invention of the steam engine prophesied the end of muscle-driven vehicles on land, just as it prophesied the end of wind-driven vessels on water. A century ago a trip from New York to the Pacific Coast was a matter of bumping over rough roads for several weeks on a horse or in a covered wagon. Today this same overland journey is a matter of gliding on smooth steel rails for less than three days in a streamlined train.

The first successful steam locomotive was invented by George Stephenson, an Englishman, early in the nineteenth



T. F. Healy Collection

Stephenson's Rocket was the first successful steam locomotive

century. By 1829 Stephenson sent one of the earliest steam trains over a trial run. Here is how an observer described the event: "It seemed indeed to fly, presenting one of the most sublime spectacles of human ingenuity and human daring the world ever beheld. It actually made one giddy to look at it, and filled thousands with lively fear for the safety of the individuals who were on it, and who seemed not to run along the earth, but to fly, as it were, on the wings of the wind. Within the vehicle, nicely poised on springs, and covered in to exclude the external current of air created by its motion, you might imagine you were in a state of perfect rest, while you are flying along the surface with the speed of a racer. Then the steam horse is not apt, like his brother of flesh and blood, to be frightened from his propriety by sudden fancies which defy the prudence and skill of the driver. Explosion, if it takes place, will not injure the passengers, for they are in a separate vehicle, and the enginemen may be trusted with the care of their own lives. In daylight, and with good arrangements, travelling in the steam coach, at 20 miles an hour, may be much more safe, as well as pleasant, than in any ordinary coach at eight or nine."

The average speed of this train that "seemed indeed to fly" was 15 miles per hour!

Little more than a century separates the earliest steam train from the mighty steam trains of today. Instead of "seeming to fly" at 15 miles per hour, the modern steam trains almost actually can fly at a speed of from 60 to 80 miles an hour. Instead of pulling a weight of less than 20 tons, the modern locomotive can pull at high speed a weight of more than 1000 tons.

End of the Steam Railway. Just as improvement in the steamship has brought it nearer to the end of its period of usefulness, so has improvement in the steam railway brought that means of transportation nearer and nearer to its end. The increasing demand for speed requires more and more powerful locomotives; more powerful locomotives require more fuel. In order to carry and burn more fuel, the locomotives and tenders must grow ever larger and heavier, as long as they continue to be made of iron and driven by steam.

But there is every indication that development in this direction will not continue. Lighter and faster aluminum trains, powered by oil-burning Diesel motors, are already streaking across the landscape. An entire passenger train

Kaufman-Fabry

The age of the steam railway is nearing the end

of this newer type may weigh only one fifth as much as a passenger train made of iron. It may be able to carry enough fuel and water to run half again as long as a steam train can travel without stopping. It may reach a speed of 120 miles an hour. And it can do all this for a cost well under 10 cents a mile for fuel, which is very much less than the cost of operating a steam train. Do you see, then, why the end of the steam railway is in sight?

Exercise. Go to the library and look up more facts about the steam train and the Diesel-powered streamlined train. Compare them in detail for comfort and efficiency and report your findings in class.

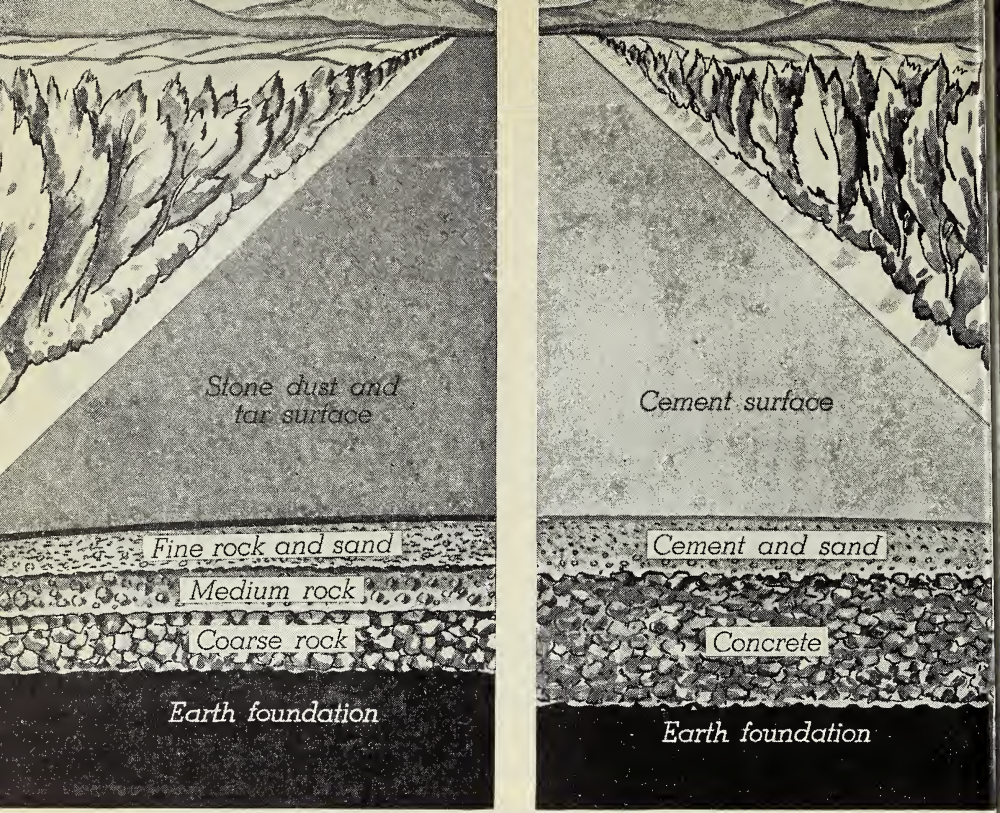
The Era of the Automobile. Just as the invention of the steam engine led to the steamship and the steam locomotive, the invention of the gasoline engine led to the automobile and the airplane. This engine, which you studied in Chapter Nine, made as great changes in the life of the twentieth century as the steam engine made in the life of the preceding century. One of the chief changes was in the highways of land transportation.

Before the automobile was invented the best roads were privately owned turnpikes which stopped the traveler at frequent intervals to collect toll. The best of these turnpikes were built after a design invented by a Scotchman, John MacAdam, and were called "macadam" roads. These roads were built in shallow troughs scooped in the ground. Large stones were spread on the bottom, and these were covered with layers of loose rock ranging in size from medium to fine. The surface of the road was made of fine sand or rock powder bound together by tar.

The macadam road was excellent for the horse and buggy, but it did not stand up under the wear and tear of the heavier and faster automobile. It was rapidly replaced by stronger highways, made in most cases of concrete. The concrete road is laid in a deeper and wider trough than that of the old macadam roadbed. A strong, thick foundation of concrete (sand, crushed stone, and cement) is first built on the ground. Above this is spread a thinner layer of sand and cement (in some cases fine stone and tar are used for the top layer). The construction of these two types of roads is shown in the illustration on page 382.

The early automobile was not always a perfect blessing

T. F. Healy Collection



The macadam road (left) was the pride of horse-and-buggy days.
The concrete highway (right) is better suited to motorized tra

The automobile brought not only stronger roads but wider and straighter ones. It vastly increased the number of roads and put all governments in the business of building them. It speeded up life in many different ways. So long as fuel is cheap the automobile and the automobile highway will probably continue to improve. Whether our lives improve as a result of all this may be another matter.

Exercise. Make a list of the advantages and disadvantages of the automobile era. Is the automobile a blessing or a curse?

The Era of the Airplane. Change crowds on the heels of change in this day of rapid transportation. Travel by automobile no sooner began to cut into travel by train than the airplane arrived to steal passengers from both.

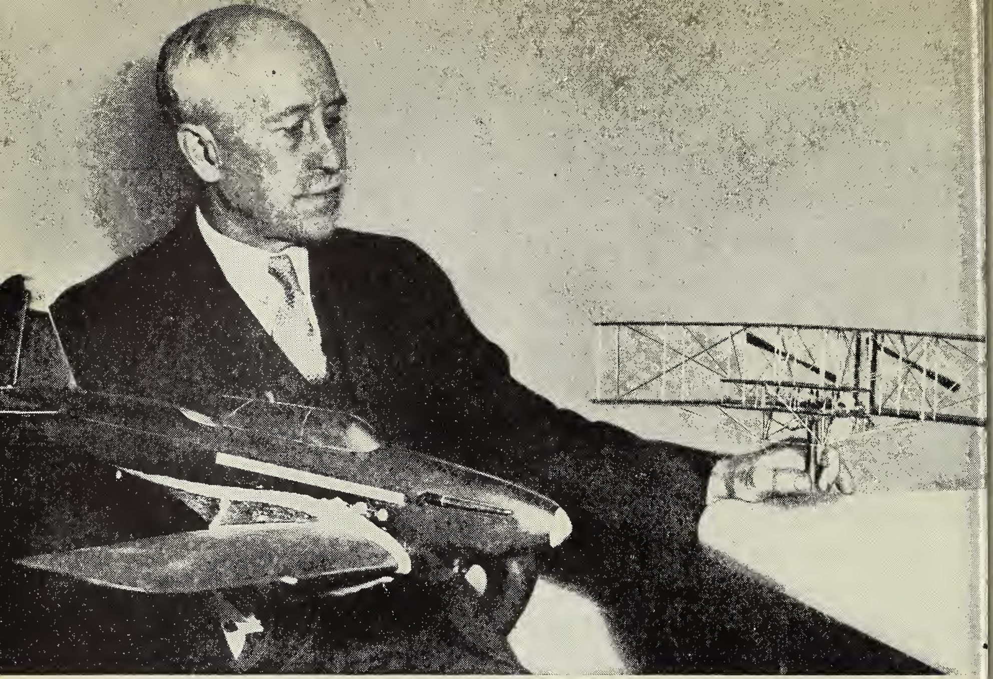
On December 17, 1903, Orville Wright sent the following telegram to his father from Kitty Hawk, North Carolina: "Success four flights Thursday morning all against twenty-one mile wind. Started from level with engine power alone. Average speed through air thirty-one miles. Longest 57 seconds. Inform press. Home Christmas."

Newspapers immediately carried this news to the world, the news of the first successful flight by a heavier-than-air machine driven by a gasoline motor and a pilot.

It is less than forty years since the Wright brothers, Orville and Wilbur, took to the air. Their first crude machine, together with the pilot, weighed 750 pounds. It was driven by a gasoline motor of 12 horsepower. The photograph on page 384 shows a recent picture of Orville Wright comparing a model of this plane with one of a plane built some thirty years later. As in the case of the automobile, the improvement of the airplane has been almost unbelievably rapid.

The successes of the Wright brothers were the result of experiments carried on through several years. These brothers were not the first to experiment with flight in machines heavier than air, nor was their machine the first to rise off the ground by its own power. If you study the history of the airplane, you will be surprised to learn how much had been done before the time of the Wright brothers. Several successful engineless gliders had been made. The Wright plane, however, was the first plane to fly and carry a pilot.

Small model airplanes driven by simple compressed-air motors had been demonstrated as early as 1848. Models powered with steam engines were successfully demonstrated



Wide World

This photograph of Orville Wright is a symbol of the almost unbelievably rapid progress in the development of the airpl

as early as 1893. In 1896 Langley built a steam-driven machine weighing twenty-six pounds which flew by its own power and continued in flight for about one and one-half minutes. In 1903 Langley experimented with an airplane designed to carry a pilot, but his efforts were not successful.

The flights at Kitty Hawk were the beginning of a great new industry. Improvements now came very rapidly. In 1905 Wilbur Wright flew for thirty-eight minutes over a distance of about twenty-four miles. It was about 1908 that competition for new records began. During this year Wilbur Wright flew with a passenger. In 1909 a Frenchman (Louis Bleriot) flew across the English Channel. The picture on the opposite page shows Bleriot on this historic flight. Ten years later (1919) Alcock and Brown flew the Atlantic from Newfoundland to Ireland. In 1927 Lindbergh flew alone from New York to Paris.

In 1934 Sir Charles Kingsford-Smith and a companion flew from Brisbane in Australia to Oakland, California, a distance of 7365 miles, with but two stops. Since then long flights have become a commonplace. Clipper ships now carry passengers and mail across both the Pacific and the Atlantic Ocean on schedule. Businessmen fly from New York to Los Angeles every day.

Exercise. Make a study of some of the famous long-distance airplane flights and prepare some short talks to present in class.

The airplane is the fastest machine that was ever invented. Planes used for carrying passengers travel at speeds between 150 and 250 miles per hour. A plane powered with a motor of 3500 horsepower has flown on a straight course as fast as 440 miles per hour, or more than 7 miles in one minute. A pilot could not ride at this speed in an open cockpit, for he would be killed by the force of the air pres-

riot's flight across the English Channel in 1909 was one of the most daring achievements of the early days of aviation sure against his body. If he were merely to extend his hand outside the cockpit, he would meet an air pressure of about 90 pounds to the square inch. Applied against the palm of the hand and the open fingers, this pressure would amount to about 1 ton—certainly enough to break the bones of the hand.

The Future of Transportation. As you review the progress of mankind in the control and use of energy for transportation, you may ask what the future holds in store. May we expect further increase in the speed of trains, automobiles, and airplanes? Predictions, of course, must be made on the basis of what is known at the present and are therefore frequently wrong.

We might venture a guess, however, that the automobile is already developed to or very near to the point of its greatest possible speed. The new streamlined trains, on the

This modern "stratoliner," flying high above the surface
of the earth, is a sample of the passenger airplane of the fut

Pan American Airways

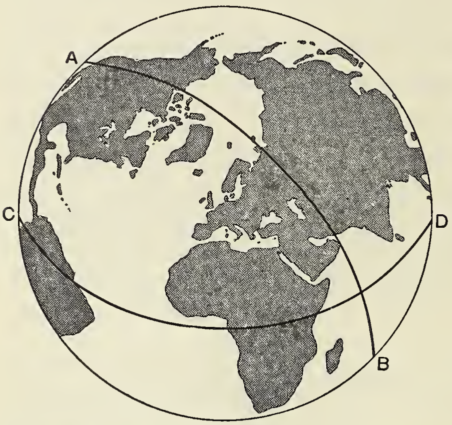
other hand, will certainly increase the rate of travel by rail. Some of the obstacles preventing increases in speed of automobiles do not apply when wheels are made to run on rails. Train speeds up to at least 150 miles an hour seem reasonably possible. It seems likely, too, that the time is not far distant when airplanes will fly through the upper air at an altitude of possibly 30,000 feet. At this altitude air is but one third as dense as at sea level, and in this thin air airplanes can certainly travel very much faster than most of them do today in the denser air near the earth.

THE PROBLEMS OF MEASURING SPACE AND TIME

Distance and Time in an Age of Speed. It is easy to see that our ideas of distance and time must change as transportation becomes faster and faster. Only a century ago Philadelphia was a *two-day* journey by stagecoach from New York; today it is less than *two hours* by train and only a fraction of an hour by plane. San Francisco today is nearer to New York by plane than Philadelphia was by stagecoach in the early nineteenth century. In this age of speed, how do we find our way about the earth and how do we tell time?

The answer is that men have always had these problems in one form or another and have solved them as they went along. The early Phoenicians and other early mariners had to know their position and their distance and direction from home when out upon unknown waters. They used the sun and the stars to help them in this, and what knowledge they had of the shape and motions of the earth. Today our measurements of space and time are based on the same type of observations, perfected through years of study by many different people.

Latitude and Longitude. From earlier work in geography you know that positions on the earth are determined by latitude and longitude. These words both come from the Latin, one meaning "breadth" and the other "length." The ideas behind these words, like the words themselves, come from the ancient world.



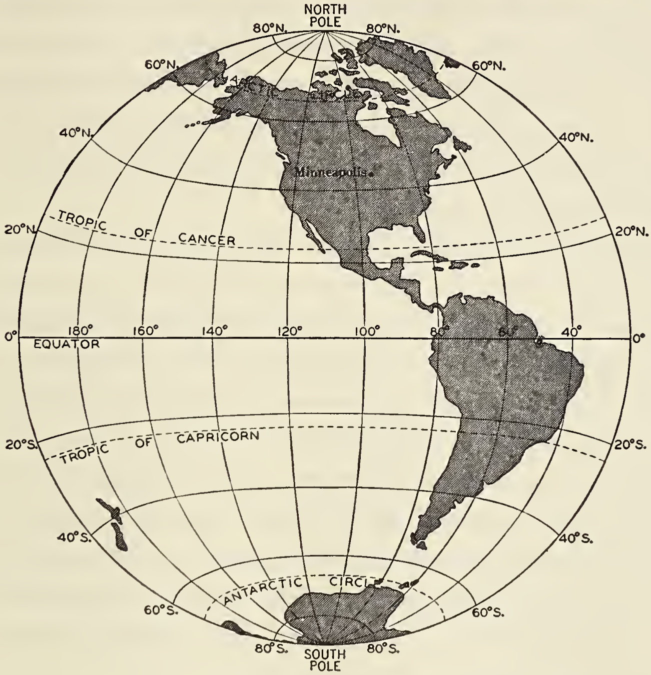
Because the earth is a sphere, distance measured round it in any way is distance round a circle

In your study of mathematics you have probably already measured circles and know that a circle is equal to 360 degrees. A half circle, then, is 180 degrees, and a quarter circle is 90 degrees. Since the earth is a nearly perfect sphere, any part of the distance around it, measured in any way, is really a distance measured around some part of a circle. The diagram on this page will illustrate this. If you travel, for example, from *A* to *B* or from *C* to *D*, you are traveling along a circle.

The fact that distance traveled on the surface of the earth is really distance on a circular line forms the basis for determining latitude and longitude. Imagine two circles drawn round the surface of the earth. One extends from east to west round the earth halfway between the poles and is called the *equator*. Imagine the other circle extending north and south through the poles.

Now let us see how we can measure distances north and south. Remember that north always means toward the north pole, and south always means toward the south pole.

The equator is, as you know, a great circle round the earth just halfway between the north pole and the south pole.



Parallels of latitude are used for determining distances north and south of the equator. Meridians of longitude are used for determining distances east and west of the prime meridian

Any point on the equator is said to be at 0 degrees latitude; points north of the equator are in *north latitude*, and points south of the equator are in *south latitude.*

A line drawn from the equator to either pole is a quarter circle. Therefore there are 90 degrees of latitude between the equator and either pole. The north pole, then, is located at 90 degrees north latitude, and the south pole is located at 90 degrees south latitude.

If you look at a map of the world, you will see a line marking the position of the equator. Paralleling the equator, other lines are drawn north and south of it. Just as all points on the equator are at 0 degrees latitude, so all points on any given *parallel of latitude* are at the same number of degrees of latitude. Minneapolis, Minnesota, and Grenoble, France, for example, are both very close to the 45th parallel north of the equator. They are therefore both at 45 degrees north latitude, which is exactly halfway between the equator and the north pole.

Meridians of longitude are used for determining distances east and west. To represent longitude, meridians are drawn from pole to pole, cutting the parallels of latitude at right angles, as shown on page 389. Since there is no fixed line such as the equator to use as 0 degrees longitude, one had to be selected. Today all countries use as the 0-degree, or *prime, meridian*, the one that runs through Greenwich, England, the home of the British National Observatory. Longitude is measured from 0 degrees to 180 degrees eastward, and from 0 degrees to 180 degrees westward. The 180th meridian is either east or west, one half of the way round the world.

With this system you can locate any point exactly, merely by determining its position north or south of the equator (the latitude) and its position east or west of the prime meridian (the longitude). Minneapolis, which we found to be at 45 degrees north latitude, is also close to the 93d meridian west of Greenwich. Its position on the earth is therefore 45 degrees north latitude and 93 degrees west longitude, or, as generally abbreviated, Lat. 45° N., Long. 93° W.

Exercise. Look up your home town or city on a map and determine its latitude and longitude to the nearest degree.

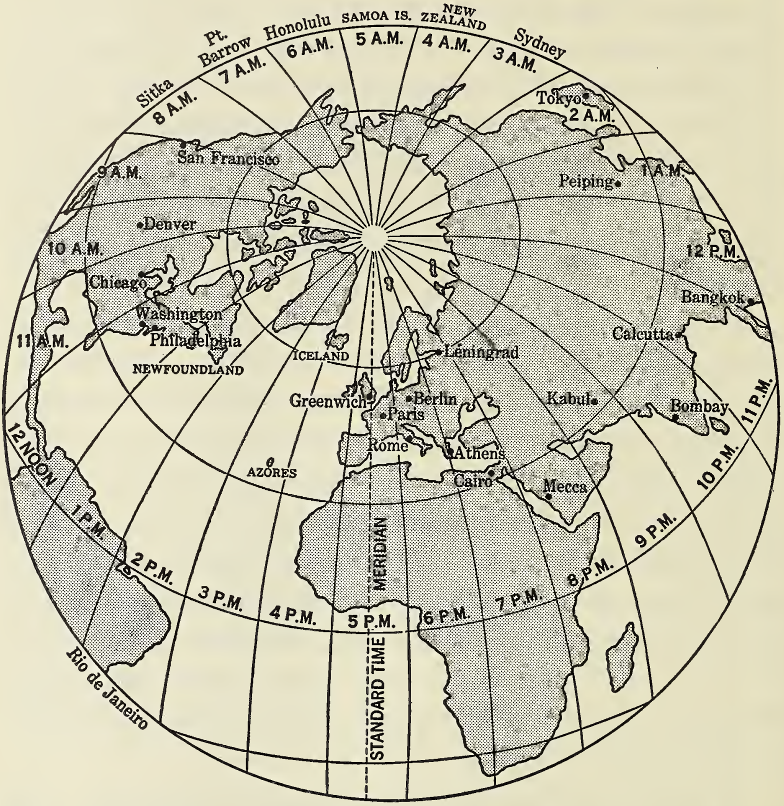
Why Time Differs at Different Places. Some of you may have listened to radio broadcasts from Europe. In the eastern part of our country you may have heard the king of England at six o'clock in the morning. If so, perhaps you wondered why a king should get up as early as that to make a speech. Strange as it may seem, however, when it is six o'clock in the morning in New York, Boston, or Philadelphia, it is eleven o'clock in the morning in England. And eleven o'clock is not so very early in the morning, even for a king.

Perhaps you have listened to broadcasts of football games between rival Eastern colleges. When the Dartmouth-Cornell game is over at about five o'clock in the East, those of you living on the eastern coast of the United States may have turned the dial and heard the beginning of a broadcast of the California-Stanford game on the western coast. You sit under electric lights in the East and listen to a description of a game being played in brilliant sunshine on the Pacific Coast. Similarly, those of you who live in the Far West may listen before and during lunch to a broadcast of a game which is being played in the East in the afternoon.

How may these common experiences be explained? Will your knowledge of latitude and longitude help you in understanding them? Is there any relationship between them and the shape and motions of the earth? Let us see.

The earth, as you know, turns on an axis at a uniform rate. So far as is known, there is no force acting either to increase or decrease this rate. The time required for one rotation of the earth may be measured by the interval of time between the instant the sun is directly over a meridian and the instant it is next over the same meridian. This length of time is called one *sun, or solar, day.*

It is noon on a meridian at the instant the sun is directly over that meridian. Obviously, then, it cannot be noon at the same instant at different positions on the same east-and-west line, or parallel of latitude. It is noon at the same time, however, at all positions north and south on the same meridian of longitude. *The position of noon, then, moves from east to west as the earth turns from west to east.*



The shape and rotation of the earth determine our scheme for telling time

Since custom has decreed that there shall be twenty-four hours in one day, the earth makes one twenty-fourth of a complete turn in an hour. When it is noon at one place, it must be one hour before noon at a position 15 degrees farther west. "Why 15 degrees?" you may ask. Since there are 360 degrees in a circle, you can see that during every hour every point on the earth turns through 15 degrees of longitude ($360 \div 24 = 15$).

Consider now the difference in location of various points and their relation to the sun at a particular time. Philadelphia is at 75 degrees west longitude. St. Louis is at 90 degrees west longitude, Denver is at 105 degrees west longitude, and Yosemite National Park is at 120 degrees west longitude.

When it is noon in Philadelphia it is one hour before noon in St. Louis, two hours before noon in Denver, and three hours before noon in Yosemite National Park. One hour after the vertical rays of the sun are over the meridian that passes through Philadelphia they will be over the meridian that passes through St. Louis, for in this interval the earth will have turned through 15 degrees. If you look at the map on the opposite page, you will find that when it is noon in Philadelphia it is midnight over the plains of central and southern China.

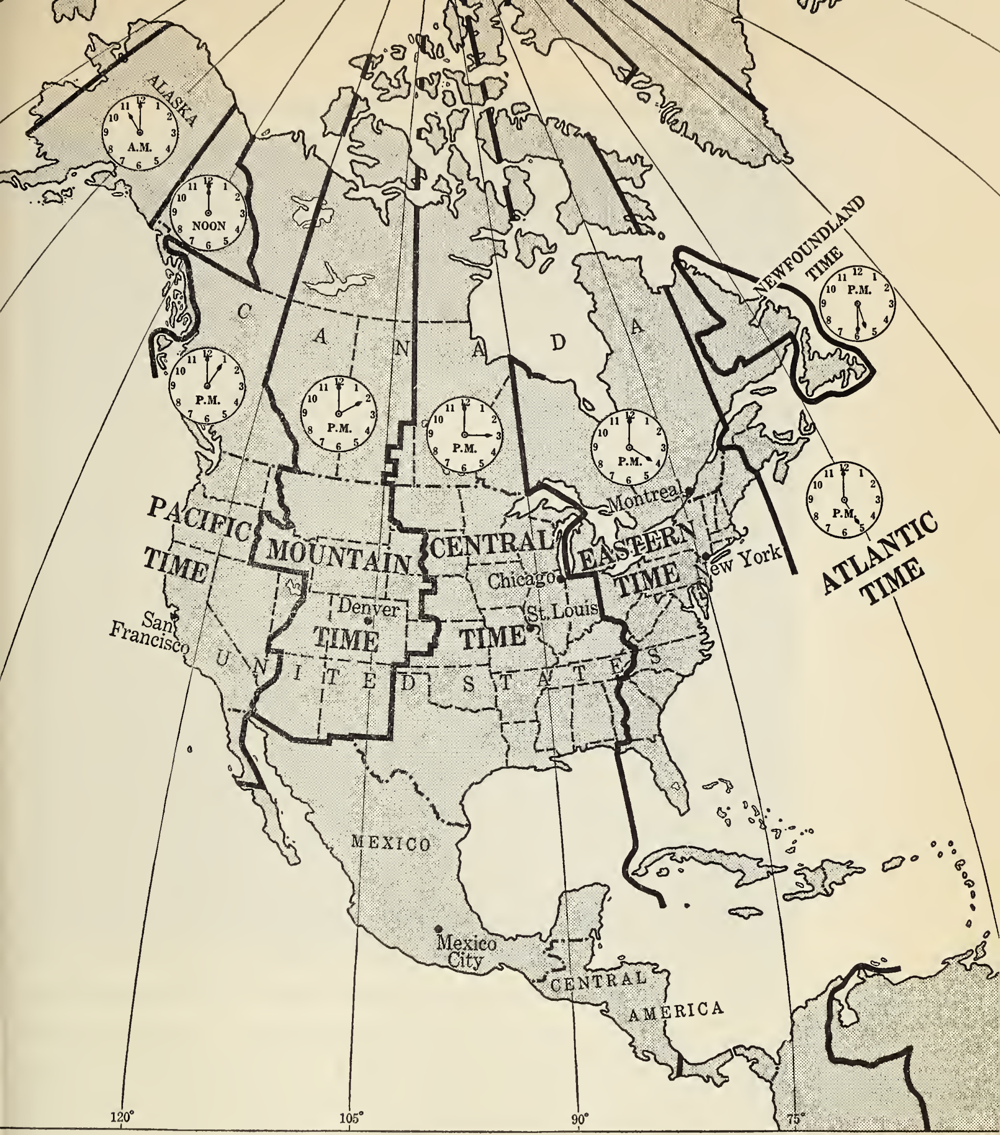
The Inconvenience of Telling Time by the Sun. Here, it would seem, is a good basis for a scheme of telling time. Why not use solar time as a unit of measurement? The sun would be a kind of universal clock. The question "What time is it?" could be answered with "Why not look at the sun?" As you study this matter more deeply, however, you begin to see that solar time would cause a great deal of inconvenience.

Noon to one person would not be noon to another person living east or west from that person. You must think of noon by solar time as moving from east to west. If a person said, "I will see you at noon," he would have to say whether he meant noon according to his solar time or the solar time at the point where the other person lived. If a railroad used solar time, it would have to indicate whether the time of arrival of trains at a certain point was local solar time or not. With this plan, too, no two places would have the same time unless they were located on the same meridian.

Time Belts. In 1864 an international congress was held in Washington for the purpose of arriving at some definite universal time plan. At this congress it was agreed that the meridian of 0 degrees, at Greenwich, England, should be *the standard time meridian.* Further, it was decided that a number of time belts should be set up, and that within each of these belts the same time should be in effect.

How should these belts be determined? The answer to this question was very simple. The members of the congress knew, as you know, that the earth turns through 15 degrees of longitude each hour, and that there are twenty-four hours in a day. Since this is so, they said, let us place the boundaries of the time belts 15 degrees apart. When it is noon at Greenwich at 0 degrees longitude, all accurate watches within the 15-degree zone, or *belt of longitude,* which has Greenwich in the middle indicate noon. The middle of the next time belt is at 15 degrees west longitude, the middle of the next at 30 degrees west longitude, and so on round the earth.

Time Belts in the United States. In the United States there are four time belts. They determine what is called Eastern time, Central time, Mountain time, and Pacific time. Each belt is about 15 degrees wide. These time belts are indicated in the drawing on the opposite page.



ere are four time belts in the United States, but eight in Canada and Alaska. Why should the time belts be more numerous in the north?

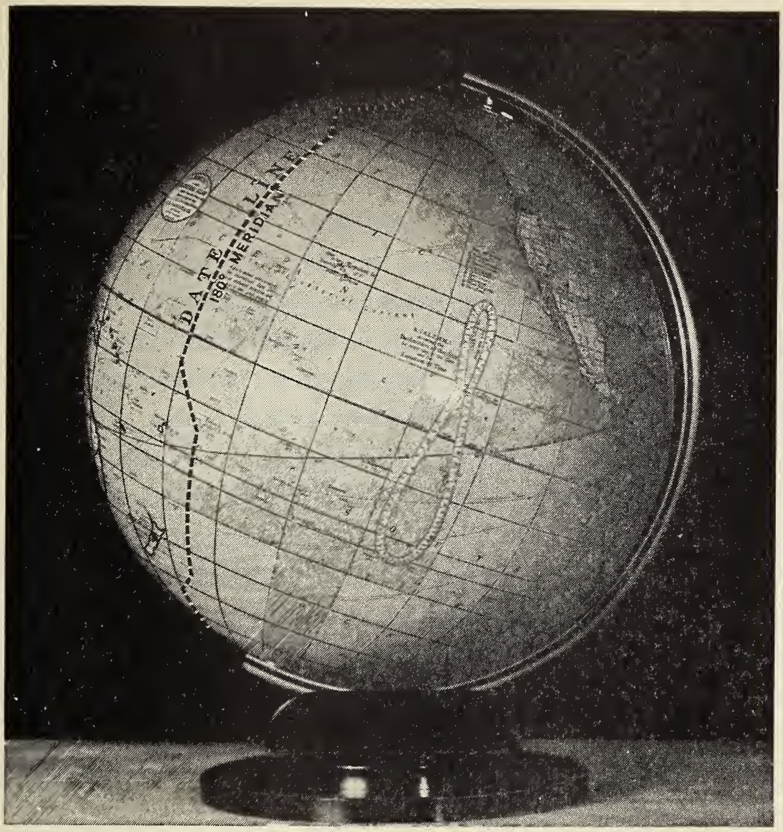
You can see that the boundaries of the belts are far from straight. Can you guess why this should be so? Consider a city located directly on the boundary meridian of a time belt. Would it be very convenient if one side of the town had Central time, while the other side had time an hour later or earlier? Practical matters such as this determine just where the boundaries of time belts are placed, but they are always about 15 degrees apart.

Let us see how these time belts are used. When the traveler goes from one time belt to the next, he must change his watch by one hour. When, for example, it is three o'clock in the Central time belt, it is two o'clock in the Mountain time belt. As he travels from east to west he must set his watch *back* one hour as he moves from one time belt to the next. As he travels from west to east he must set his watch *forward* as he moves from one time belt to the next.

Exercise. How should you change your watch if you traveled across the United States from New York to San Francisco? Use one railroad timetable showing stations between New York and Chicago. Use another timetable showing stations between Chicago and San Francisco. List the large cities in which "the time changes."

Standard Time. The time kept by ordinary clocks and watches is called *standard time.* There is one meridian in each time belt at which standard time and solar time are exactly the same. In the Eastern time belt this meridian is the one that passes through Philadelphia. At the eastern edge of a time belt the solar time is about thirty minutes ahead of standard time, and at the western edge of the belt the solar time is about thirty minutes behind standard time. In other words, if you live on the edge of a time belt, the sun is not directly over the meridian where you live when the clocks in your city indicate noon. *Standard time may be thought of as the average solar time of a given time belt.*

International Date Line. At the latitude of Washington, D.C., a spot on the surface of the earth is carried forward,



The International Date Line nearly corresponds to the 180th meridian

as the earth turns, at a speed of about eight hundred miles per hour. If a person had an airplane capable of this speed, he could start westward from Washington at noon and continue his travels at the latitude of this city all the way round the earth with the sun all the time in the position of noon. If, instead, he traveled eastward at this speed he would, if he started at noon, arrive in just twelve hours at a position in which it would again be noon. In another twelve hours he would be back at his starting place, and it would be noon again.

What does this mean, practically? It means that a traveler going westward must set his watch backward every time he crosses a time belt. If he continues round the world, traveling westward, he will set his watch backward one hour twenty-four times, or one full day, during the journey. In this way he would seem to lose a day in the course of a trip round the earth. But when he returned to his starting place on what would seem to him to be Monday, he would find that it was really Tuesday and that he had not lost the day after all. Similarly, a traveler going eastward round the earth would seem to gain a day.

The International Date Line has been established in order to set this right. This line nearly corresponds to the 180th meridian, as the illustration on page 397 shows. When a traveler crosses the Date Line, he changes time by one full day. If it is Monday on the east side of the line, it is Tuesday on the west side of the line. Thus a round-the-world traveler going westward gains a day at the Date Line which he would otherwise lose. Similarly, a traveler going eastward loses a day at the Date Line which he would otherwise gain. The result is that whether moving westward or eastward, the round-the-world traveler returns to his starting point with his calendar correct.

Days, Months, and Years. A day is defined as the length of time required for one complete rotation of the earth on its axis. This may be measured by using the sun as a point of reference. A solar day, as we have seen, is the interval between the time when the sun is directly over a meridian and the time when it is again directly over the same meridian. Sometimes astronomers measure days by some other star instead of the sun. In that case they speak of *sidereal days* (star days) instead of solar days.

A *lunar* month, about twenty-nine and a half days, is the interval from one full moon to the next. All the changes in the moon from one full moon until the next are completed 12.4 times in one year. The interval between one full moon and the next full moon is divided into four phases, or stages. The *week* is an interval that corresponds closely to one of the moon's phases.

The *year*, like the day, is a natural unit of time. It is the time required for the earth to make one revolution round the sun. The length of the year has been measured very carefully. It is about three hundred sixty-five and a fourth days long. More accurately, it is 365 days, 5 hours, 48 minutes, and 46.98 seconds.

How We Came by Our Present Calendar. The first calendar similar to the one we use today was made in 46 B.C., during the time of Julius Caesar, and for that reason it was called the *Julian calendar*. It was said that Caesar got the idea from the Egyptians. This was not, of course, the first calendar. Many people, including the ancient Greeks, Egyptians, Mayas, and Babylonians, had calendars. Theirs were based on the changes of the moon, however, while the Julian calendar alone was based on the earth's revolutions round the sun.

The Julian calendar divided the year into twelve months of about equal length. After a slight change made by Augustus Caesar, who followed his uncle Julius, the Julian calendar consisted of seven months with thirty-one days; four months with thirty days; and one month with twenty-eight days. This is a total of three hundred sixty-five days. Since the year is really about three hundred sixty-five and a fourth days long, one day was added to the calendar every fourth year.

Since the year is not exactly as long as three hundred sixty-five and a fourth days, there was an error in the Julian calendar. The year is really about eleven minutes and fourteen seconds (or seventy-eight ten-thousandths of a day) less than three hundred sixty-five and a fourth days. The year of the Julian calendar, then, was too long by this amount. In a hundred years this error mounted to about three fourths of a day, and in four hundred years to three days. As the centuries passed, it became evident that a correction must be made.

In 1582 Pope Gregory XIII reformed the Julian calendar. Since the change was made more than sixteen centuries after Julius Caesar, the error of the calendar by that time had amounted to about ten days. The Pope announced that ten days should be dropped from the month of October, 1583, and that the fourth of the month should be followed immediately by the fifteenth. He also ordered that years divisible by 100 should not be leap years unless they are also divisible by 400. As you can see, if you care to figure it, this shortened the Julian calendar by three days in four hundred years.

The calendar worked out by Pope Gregory is called the *Gregorian calendar* and is the one that we use today. There is a little error in it, but it amounts to only one day in thirty-two hundred years. Three hundred and fifty years have passed since Pope Gregory corrected the calendar. It will not need correction by as much as one day for another twenty-nine and a half centuries.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The dog was probably the first domesticated animal and the first beast of burden.

2. The first real boat was invented by the early Egyptians.

3. There are several types of primitive boats in use today, but only for transportation on inland waters.

4. Fulton's *Clermont*, the first steamboat, made its famous trip up the Hudson River in 1807.

5. A stone sinks in water because it is not buoyed up by a force which is equal to the weight of the water displaced.

6. The submarine is the only boat that can disobey the law of buoyancy.

7. The steam railway is just now entering what will undoubtedly be its period of greatest usefulness.

8. The early macadam roads of the Roman Empire are still in use.

9. The airplane, like the automobile, is probably already developed to the point of greatest possible speed.

10. Latitude is measured east and west of the prime meridian.

11. When it is noon in New York it is midafternoon in Los Angeles.

12. The most accurate and convenient way of telling time is by using the sun.

13. Standard time is the same as solar time.

14. The International Date Line confuses travelers and really should be abolished.

15. The calendar which is in use today will never need correction again.

Questions for Discussion

1. For many years people have argued whether a ship that sinks in deep water goes all the way to the bottom of the ocean or whether the pressure of the water will support it at a certain level above the bottom. What do you think? See if you can find the answer.

2. Are automobile trucks as efficient as freight trains for the transportation of most goods?

3. What advantages are claimed for daylight-saving time? What disadvantages?

Things to Do

1. Draw up plans for a raft or small boat. To help yourself in checking up on your work, you might talk over each step of it with the class. You might try to build the raft or boat from your plans.

2. There are many good books about railroading. You might look up Carter's *When Railroads Were New*, Holland's *Historic Railroads*, or Van Metre's *Trains, Tracks, and Travel*. If you want to know about the pony express, look up Chapman's book *The Pony Express*.

3. Look up the story of some famous racing car, such as Campbell's *Bluebird*, and see if you can discover how this car differs from the standard automobile in terms of power, engine design, use of fuel, and method of steering.

4. Find figures which will illustrate the growth of railroads in this country. Prepare a graph from these figures.

5. Make a similar graph for the increase in automobiles.

6. If you want to know more about the history of aviation, read Goldstrom's *A Narrative History of Aviation.*

7. Many boys and girls today belong to model-airplane clubs. They build their own airplanes and have regular competitions for prizes. Perhaps some teacher in your school would be willing to help you to organize such a club. A book that would help you is Garber's *Building and Flying Model Aircraft.*

8. If you want to know more about man's ways of telling time, see if your library has a copy of Brearley's *Time Telling through the Ages.* If you are interested in clocks or watches, look up Milham's *Time and Timekeepers.*

UNIT FOUR

THE PRESERVATION OF HEALTH

THE PRESERVATION OF HEALTH

In the last unit we studied a large variety of machines.

All of them, however, were designed for one great general purpose: the use of energy.

All were designed by the human mind for purposes conceived by the human mind.

* * *

In this unit we shall study the body in which that mind is seated and through which it is able to work.

Are we ourselves machines like the machines which we invent and control?

We are certainly devoted to the use of energy, and much that we have already studied in this book is the direct result of that devotion.

But if we are machines, just what kind of machines are we?

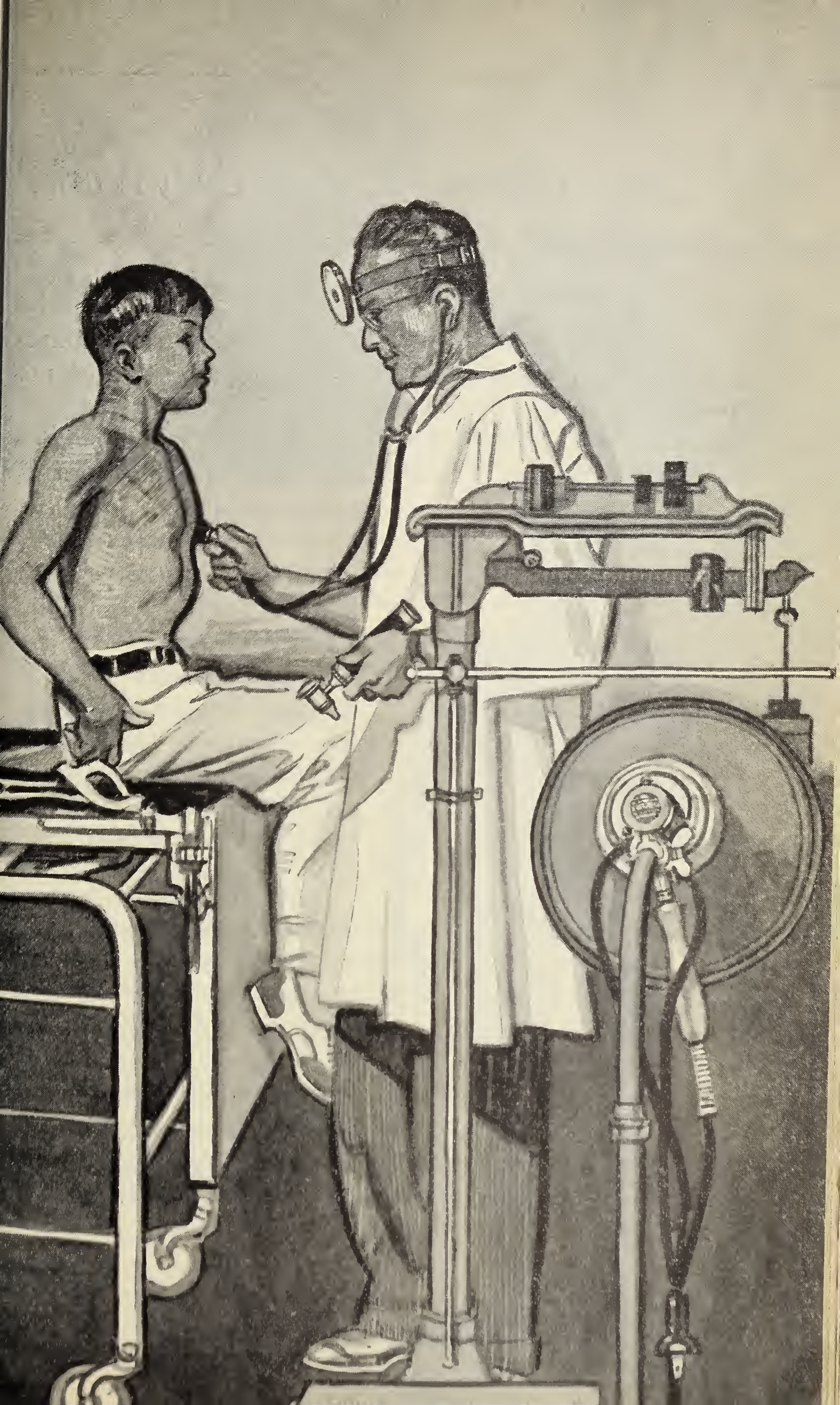
* * *

This unit will try to answer that question.

It will try to show you that though in many ways we behave like machines, we do many things that no other machine can do.

It will try to convince you that of all our possessions we ourselves are much the most valuable.

It will try to explain how best we may protect this treasure.

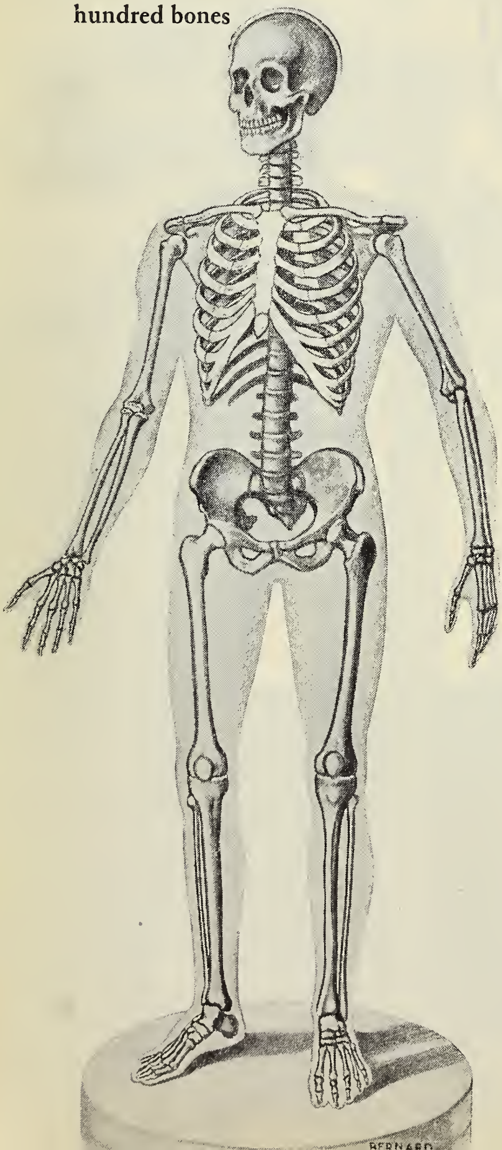


CHAPTER FOURTEEN

How Does the Human Body Work?

THE WORK OF SKELETON AND MUSCLES

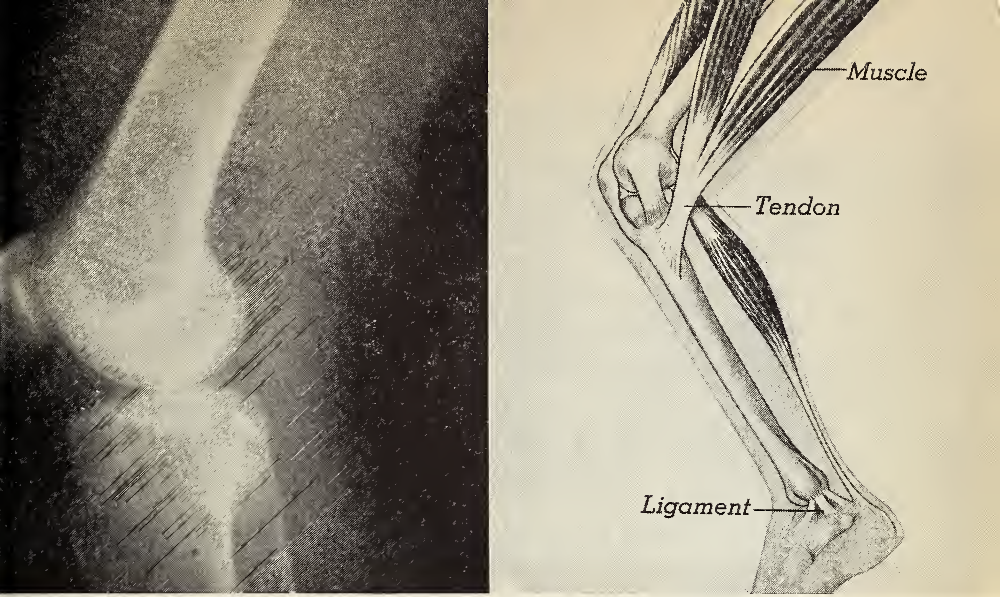
The Human Skeleton as a Machine. If we study the framework of the human body, we see in it many similarities to the machines which we have already studied. This framework, shown at the left, is called the skeleton. It is made up of somewhat more than two hundred distinct parts which are known as *bones*, connected by strong cords which are known as *ligaments*. Many of the bones fit together in *joints* and are movable one upon the other. Such bones, ligaments, and joints act as levers to assist the body in motion.



The human skeleton has more than two hundred bones

How the Skeleton Is Held Together. Unfortunately we cannot comfortably take our skeletons apart to see how they are put together. We can, however, examine a leg of lamb after dinner to see how the bones and ligaments

[1] From Andress, Goldberger, Hallock, *Doing Your Best for Health.*



The X rays reveal the way in which the bones of the leg fit together at the knee joint (left). Ligaments, tendons, and muscles serve to hold together and move the joints of the leg (right)

are related. The bones of a lamb are held together much as our own bones are.

Exercise. Get from a butcher shop some of the jointed bones of a sheep, pig, or cow. After the meat has been trimmed away from a joint, place the joint in a strong solution of salt and boil for several minutes. The ligaments will then come free from the bones and you can see clearly how the bones are fitted together.

If you could look at the bones of your own skeleton as closely as this, you would see that they are fitted together in much the same way. As you sit on a chair, observe how easy it is for you to swing your legs back and forth. How is this possible?

Study the illustration at the left above, which shows an X ray of the human knee joint. Compare this with the illustration at the right, which shows how the joints of the leg are held together by ligaments. Notice that the *muscles* (which move the joints and which we shall study in more detail later) are attached to the bones through *tendons*. Notice, too, how the bones are enlarged at the ends to give space for these attachments. Ligaments and tendons are very strong because they must hold the body together through all the wear and tear of life.

Unfortunately, the bones and ligaments sometimes fail in their duty when we handle our bodies too roughly. When we injure the attachments of our skeletons, we say that we have suffered a sprain. What should you do when you suffer a sprain? Obviously the injury will grow worse if you continue to use the damaged joint; recovery will be quickest if you keep it still. If the sprain is quite serious, it may be necessary to set the joint in a cast, so that you cannot move it until there has been time for the injury to repair itself.

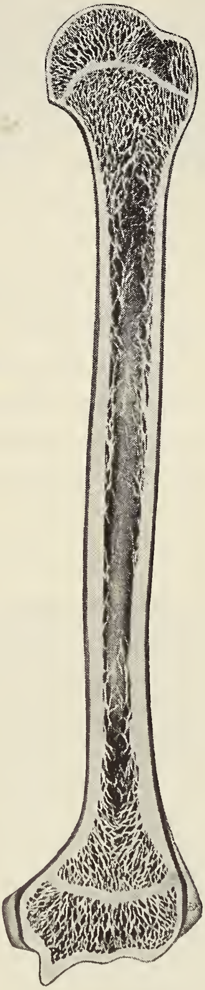
Composition and Growth of Bones. You may think of bones as hard and stiff, but you probably know that the bones of a child are not so hard and stiff as the bones of an adult. At birth the bones are flexible (that is, they will bend), and the joints move with great freedom. A child may be twelve months old or more before his bones are strong enough to allow him to stand upright. Evidently the bones of the body harden as the child develops.

In their early stages the bones are composed of tough, elastic living material, or *tissue*. The chemical elements necessary for growth and development are fed to the bones through the blood. Mineral compounds, of which calcium phosphate and calcium carbonate are in greatest abundance, deposit in the bones, causing them to harden. You may recall from earlier studies that vitamin D is necessary for the healthy growth of the skeleton. If there is not enough vitamin D in the diet, these minerals do not deposit properly, and healthy bones do not form.

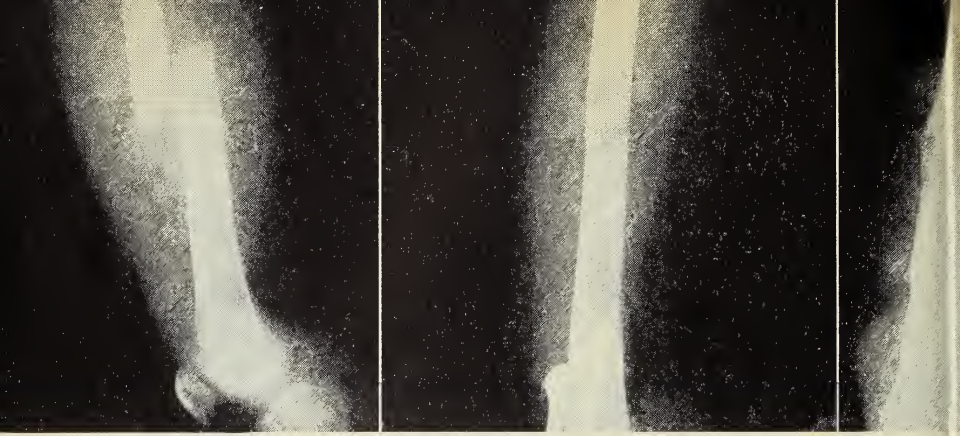
The bones harden as they grow larger. The hardening continues through the period of childhood and into adult life. This gradual development helps to explain why a child may often fall without harming himself. The same falls might result in serious injury to an older person, whose bones are more brittle.

Exercise. How the mineral matter in bone may be separated from the bone: Place a chicken bone (the "drumstick," for example) in strong vinegar or dilute hydrochloric acid. Leave it until the bone has softened so that it will bend without breaking. Pour some of the liquid into a dish and evaporate it over a low flame. The dry substance left behind is mineral matter from the bone.

If you cut this softened bone with a knife, you can see at once that the bone is hollow. The drawing at the right shows a section of the long bone of the human arm. It too is hollow. In childhood this hollow space is partly filled with a spongy bone tissue, which slowly disappears with advancing age. There is also *bone marrow* in the hollow space, a soft substance that helps to provide the bone with nourishment.



This drawing shows the relationship of bone and bone marrow in the upper arm bone of a child



A broken bone (left) when properly set (middle) will mend itself (right)

How Our Skeletons Mend Themselves. Injured bones are sad reminders of the importance of bones in the body. Without the use of even a few of them our bodies become inefficient. Fortunately, skeletons have the remarkable ability of mending themselves, an ability which no non-living machine shares. The photographs above are X-ray pictures which show a broken bone, how it was set, and how it appeared after healing.

If you could follow the healing process closely, you would see that the broken ends begin to form new cells. A tissue like that of the bones in a very young child forms across the gap and slowly hardens. The manner in which this new growth occurs is similar to the manner in which the soft bone of an infant changes to the hard bone of an adult, except that in healing the changes go on much faster than in ordinary growth. During the process of healing the bone must be carefully protected. After healing is complete, the bone is as strong as it was before.

Kinds of Muscles. The living tissues that move the bones of the body are called muscles. Through the direction of her muscles the golfer shown on the opposite page is producing motion at nearly every joint of her body. You may feel your own leg muscles tighten when you walk across a room and loosen (relax) when you sit down. These and other muscles attached to the bones are known as *skeletal muscles.*

While the skeletal muscles are most in evidence, there are others quite unlike the skeletal muscles in both structure and behavior. There is, for example, the *diaphragm*, a sheet of muscle separating the chest and the abdomen. This sheet of muscle, shown on page 414, is important in breathing. There are muscles in the walls of the arteries whose action you may feel as you count your pulse. There are other muscles in the walls of the throat, the stomach, and the intestine. In addition to these and others like them there is the important muscle of the heart.

On the basis of structure and behavior there are three different kinds of muscles: (1) striated and voluntary (skeletal muscles); (2) smooth and involuntary (muscles

Here is one way of exercising your skeletal muscles

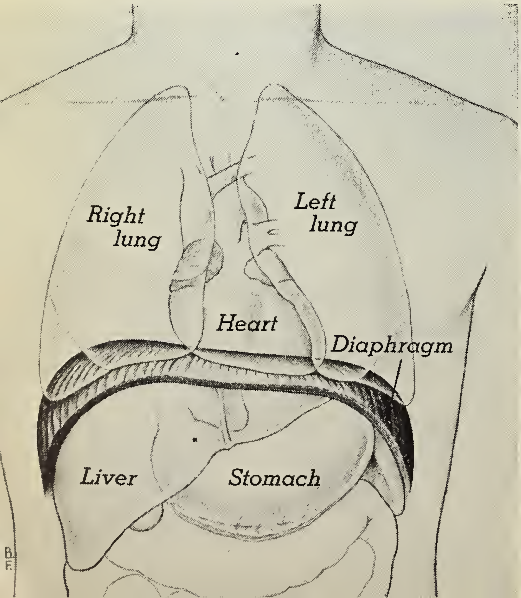
Acme

of diaphragm, stomach, intestine, and others); (3) striated and involuntary (heart muscle).

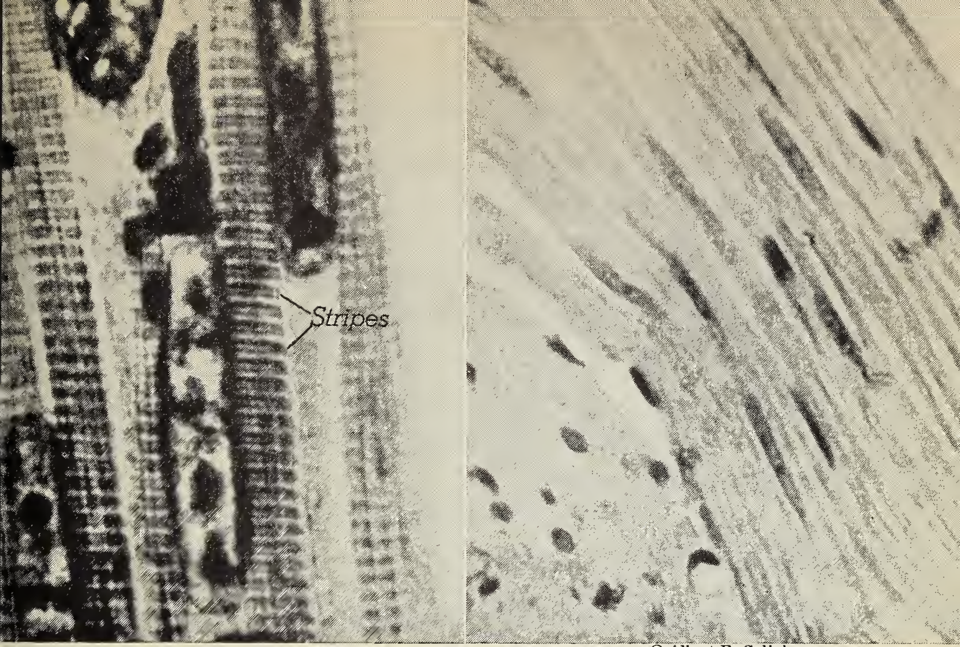
Striated Muscles. We say that the skeletal muscles are striated and voluntary. What does this mean? "Striated" is a word which means "striped," and when used in the description of a muscle refers to its appearance. You see striated muscles when you eat lean meat. Boiled muscle tissue may be easily separated into stringy *muscle fibers*, and by close examination you may see the stripes running across the separated fibers. The illustration at the left on the opposite page shows how striated muscles appear through a microscope. Such striated skeletal muscles are called voluntary because we can control them by thinking. This means that we can use them or not, as we see fit.

Smooth Muscles. In contrast, the smooth muscles work without voluntary control. We cannot by conscious effort affect the action of the muscles in the walls of the intestine. Neither can we consciously increase or decrease the rate of the pulse. You may, of course, hold your breath for a short time and thus consciously increase or decrease the rate of breathing. But normally you breathe without thinking about it. The illustration at the right on the opposite page shows how the smooth muscles appear under a microscope.

The diaphragm is a sheet of muscle tissue that helps us to breathe



The Importance of Muscles. The muscles are important because without them we could not move. The energy of food is released in the muscles, and many changes



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ped, or striated, muscles (left) move the bones of our skeletons.
Smooth muscles (right) control the movement of most of our internal organs

go on in them as they are exercised. Food and oxygen are dissolved in the blood and pumped to the muscles through blood vessels by the heart. This organ is itself a great muscle, but different from all other muscles because it is striated like the skeletal muscles and involuntary like the muscles of the other internal organs.

The food and oxygen dissolved in the blood seep into the muscles through the walls of the smaller blood vessels. There they produce a chemical change which turns the energy of the food into the energy of heat and motion. The rate at which energy is released to the muscles is determined by the rate at which oxygen can be taken into the lungs. Let us see exactly what this means.

The Oxygen Debt. Let us look at an athlete in a 440-yard dash, which is considered by many the most difficult of all track events. Let us say that the athlete, starting from rest, ran 440 yards in 1 minute. During this time he did not take in enough oxygen for his bodily needs, because at the end of the race he was tired and out of breath. Careful observations show that the energy requirements of his body during this race could have been met by 15.8 quarts of oxygen. The runner, however, was unable to take in more than 1.8 quarts during the race and so developed an "oxygen debt" of 14 quarts. By heavy breathing after the race this oxygen debt was paid.

But what goes on in the muscles of the runner while the oxygen debt is developing? Examination of a healthy muscle shows that considerable food is stored in it in the form of a starchy substance called glycogen. There is enough glycogen stored in a healthy muscle to supply energy for a considerable time. As the muscle is exercised, however, some of the glycogen is changed to a sugary substance called glucose. This in turn is changed to lactic acid, which is the same substance that gives sour milk its sour taste.

In these changes energy is released, which supplies force to the muscle. When lactic acid develops, however, the

These runners are building up an oxygen debt

University of Illinois

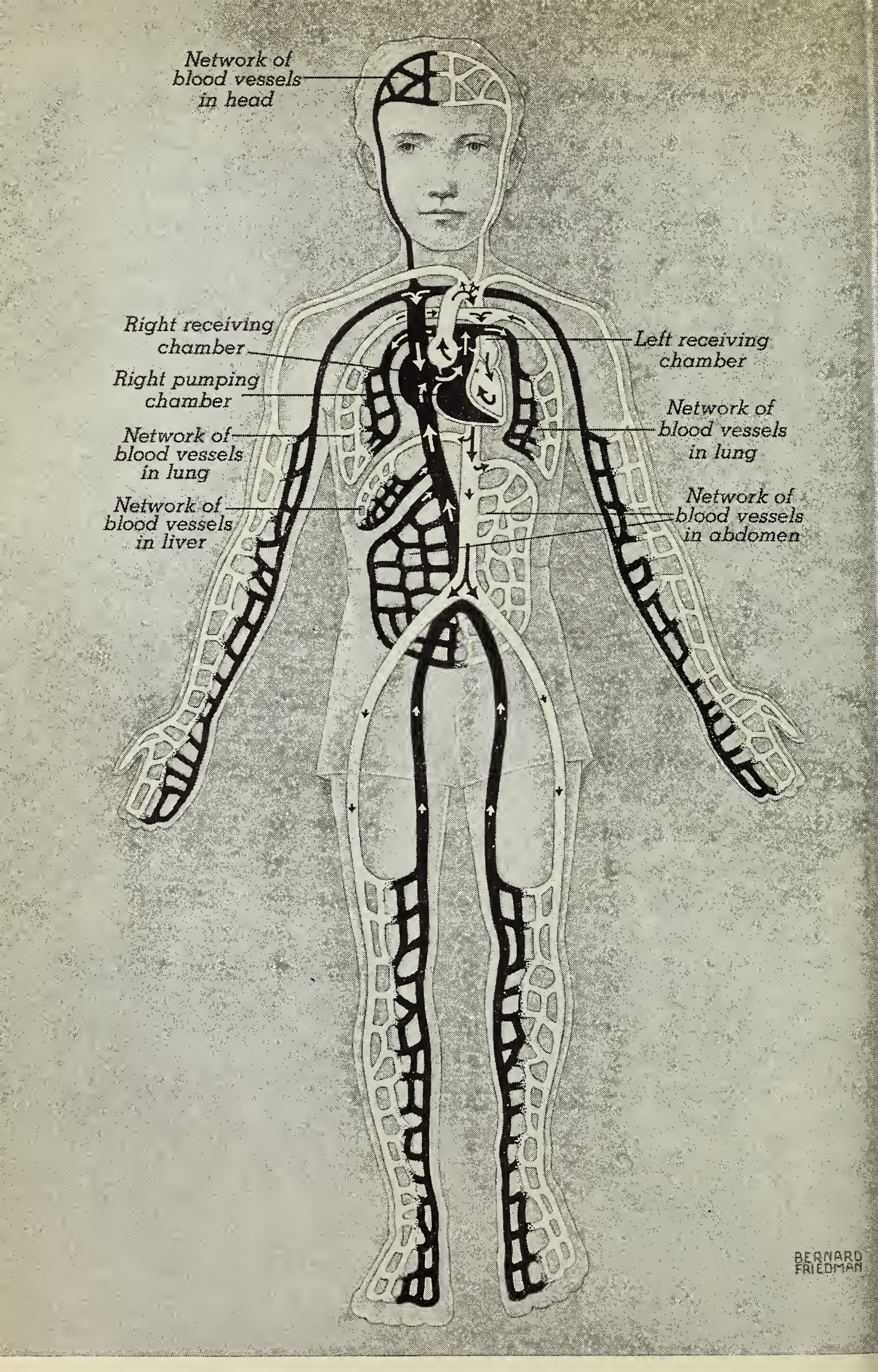
muscle grows tired. It recovers from fatigue only when some of the lactic acid is cleared away, and this can be done only with the help of oxygen. The runner mentioned above was unable to take in enough oxygen during the race to keep lactic acid from piling up in his muscles. That is why he became tired. That is also why panting after the race relieved his fatigue by bringing in enough oxygen to his muscles to reduce the overabundance of lactic acid.

THE WORK OF THE HEART AND BLOOD

Effects of Exercise. A foot race or even a brisk walk, as we all know, brings an increase in the rate of breathing. The result is that energy is released from our food at a more rapid rate than when we are quiet. Exercise, therefore, not only makes more oxygen necessary but also more food. With exercise, the body as a whole responds to the demands of the muscles. By a simple observation you can study the effects of exercise on the heart.

Exercise. After sitting quietly for a time count the pulse beats that you can feel in your wrist in a period of fifteen seconds. Then do a "standing run" by throwing yourself from one foot to the other until you have counted fifty steps. Count your pulse beats again. After you have been seated for ten minutes count your pulse beats again.

Work of the Heart. The rate of heartbeat increases with exercise because the body requires more food at such a time. The blood carries this food to the cells of the body and also removes the waste products, and the heart is the pump that keeps the blood on the move. Do you see then why the beating of the heart is so closely connected with life? If the heart stops beating, the blood stops circulating, and the cells of the body starve.


Network of blood vessels in head
Right receiving chamber
Right pumping chamber
Network of blood vessels in lung
Network of blood vessels in liver
Left receiving chamber
Network of blood vessels in lung
Network of blood vessels in abdomen
BERNARD FRIEDMAN

This diagram explains how the blood circulates through the body

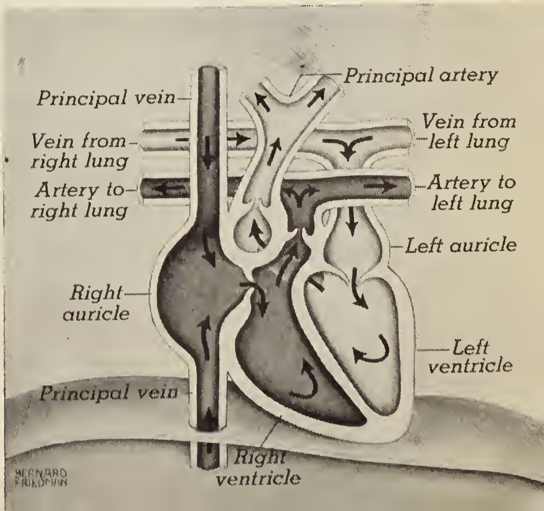
The drawing below shows how the heart is built and how it works. Blood flows into the heart through several tubes, or blood vessels, called *veins*, and out of it by way of similar tubes called *arteries*. Notice that the heart is made of four chambers, and that two large veins connect with the upper right chamber, or *right auricle.*

As the heart beats, the blood flows through these veins into the right auricle and from there into the lower right-hand chamber, or *right ventricle.* It then leaves the heart by a large artery which carries it into the lungs. Here it gets a new supply of oxygen and returns through veins into the upper left-hand chamber of the heart (the *left auricle*).

From there it is pumped into the lower left-hand chamber (the *left ventricle*), and then leaves the heart through the principal artery, the *aorta.* From there it travels to every nook and cranny of the body, as the diagram on the opposite page will show. Returning loaded with carbon dioxide and other waste from the cells, it again enters the right auricle of the heart and begins its travels once more.

Composition of the Blood. The blood is the grocery boy of the body and is forever busy carrying food to its every part. If you could examine the blood of a healthy person, you would find it a complex substance that makes up about 9 per cent of the total weight of his body. The liquid part of the blood is called the *plasma*, and floating in the plasma are the red and white blood cells, or *corpuscles.* About two thirds of the

This diagram explains how the heart pumps blood

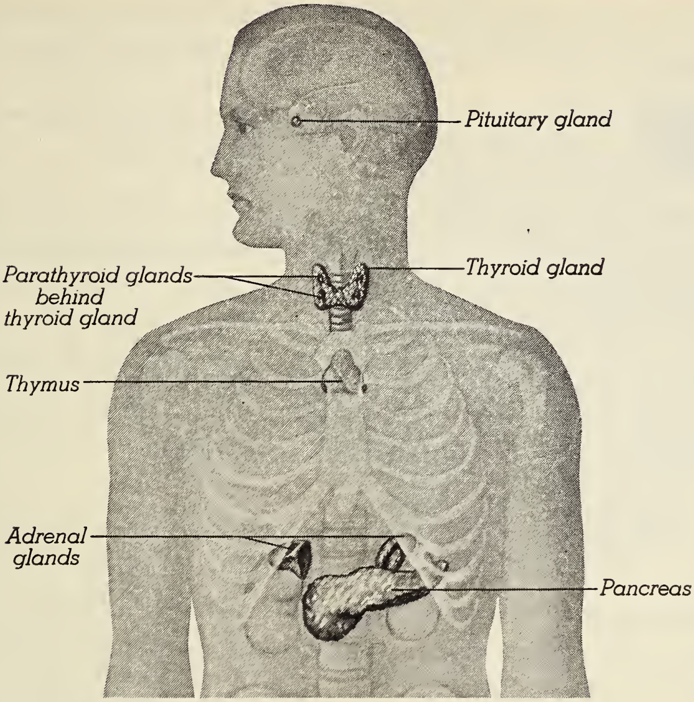


weight of the blood is plasma. The cells make up about one third.

The Plasma. Let us first examine the liquid part of the blood, the plasma. This is about 90 per cent water and 10 per cent food and mineral substances. It is interesting to notice how the different materials of the plasma are kept in balance. There is, for example, about 0.1 per cent of sugar in an average sample of plasma. This may range as low as 0.07 per cent under conditions of health or as high as 0.18 per cent. If blood sugar runs higher than 0.18 per cent, as it may after a heavy feast of candy, the surplus is carried off through the kidneys as waste. Only in illness does the percentage of blood sugar run lower than 0.07 or higher than 0.18 per cent. The amount of other substances is similarly controlled. Mineral salts are kept at about 0.6 per cent, with a normal change of not more than 0.1 per cent below or above that amount.

Other substances are found in the plasma, but they are present in very small amounts. There is a substance which causes the plasma to clot, or thicken, when it comes in contact with injured tissue. If you have had your tonsils out or perhaps some other kind of operation, you may know that you were first tested to see whether or not your blood clotted properly. You can see the importance of this. If your blood does not readily clot, special precautions must be taken to keep it from leaking away.

Glands of Internal Secretion. An important part of the plasma are substances which destroy the effects of poisons that may get into the body. There are also materials which come from a variety of glands. These organs are called glands of internal secretion because they manufacture cer-



The glands of internal secretion help to regulate the activities of the body[1]

tain substances (secretions) and then pour them directly into the blood. The diagram above will give you a general idea of the size and location of some of these glands.

The *thyroid* gland, located in the neck, produces a secretion which plays a most important part in regulating the manner in which the body uses food. A secretion from the *parathyroids* regulates the use of calcium, which, as you know, is a very important element in the growth of teeth and bones. The *pituitary* body at the base of the brain furnishes a secretion which regulates the rate of growth in the bones. A secretion called insulin, taken up by the blood as it flows through the *pancreas*, regulates the use of sugar.

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[1] From Andress, Goldberger, Hallock, *Helping the Body in its Work.*

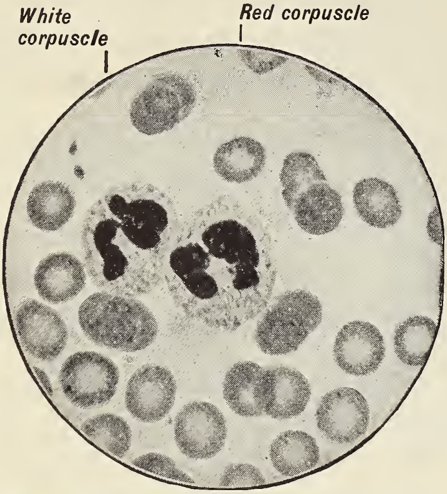
The amount of blood that would fill a box of this size would contain 5 billion red corpuscles

There are other glands of internal secretion, each one pouring into the blood its particular regulating substance. These internal secretions are called *hormones*, a word meaning "to excite" or "to cause to act." Since the hormones are necessary for maintaining a balance of activities within the body, it is easy to understand that failure of these glands to function properly will cause illness.

The Red Corpuscles. Now let us look at another important part of the blood. If you could examine a sample of blood under a powerful microscope you would see, as in the picture on the opposite page, that it contains many small particles, or corpuscles. Most of them are red in color, but some are white. You probably already know something of the functions of the red corpuscles. They combine with oxygen as they flow with the blood through the lungs, and they release the oxygen to the cells. Since every cell in the body must have oxygen for its life and growth, it is impossible to overestimate the importance of the red blood cells.

These corpuscles are extremely tiny; in a man there are normally about 5 *million* of them in 1 cubic millimeter of plasma. The little cube pictured above is just 1 cubic centimeter large. One cubic centimeter, as you probably know, contains exactly 1000 cubic millimeters. The blood required to fill the small volume of 1 cubic centimeter will therefore contain about 5 *billion* red corpuscles! In women the number of red corpuscles is ordinarily about 10 per cent less than in men.

Every day of our lives many of the red corpuscles of our blood are destroyed, and new ones are supplied. The source of supply for new ones is the bone marrow. As the result of certain diseases the total number of red corpuscles may be considerably reduced. A person suffering from a definite shortage of red corpuscles is said to have *anemia* ("without blood"). It is obvious that a condition of anemia will interfere seriously with the normal functioning of the body as a whole.



This is how a drop of blood appears under a microscope

The White Corpuscles. The white corpuscles make up the standing army of the body. Their most important work is to protect the blood from invading enemies, especially the tiny plants which are known as bacteria. The white corpuscles devour and digest these living creatures when they get into the blood. Study the picture above.

Normally there are from 5000 to 15,000 white corpuscles in each cubic millimeter of blood, or about 1 to 3 white cells to 1000 red cells. In case of disease the number of white ones may be very much greater. In any injury, as when you cut your finger, white corpuscles collect in the injured tissue and act as guards against bacteria. The pus that forms about an infected cut contains many white corpuscles.

These seem always to increase in number when more are needed. An increase in their number is evidence of infection somewhere in the body. When you are given a careful health examination, one of the things done is to count both the white and the red corpuscles.

Exercise. If there is a microscope in your science laboratory, examine a drop of blood and find the red and the white corpuscles.

THE WORK OF THE NERVOUS SYSTEM

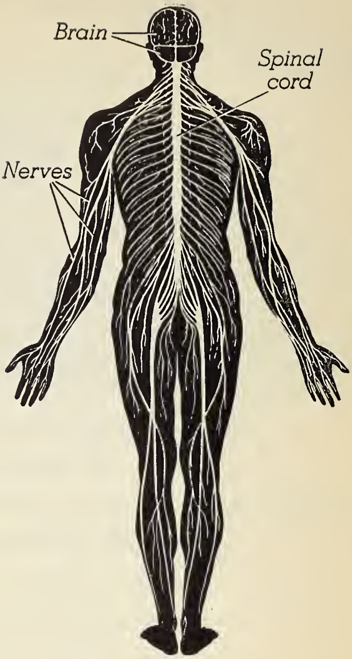
The Divisions of the Nervous System. Have you ever held your finger near a hot object and pulled it away quickly when you felt the heat? Have you ever suddenly jumped when you heard the sharp sound of an automobile horn? In such experiences as these the bones are moved by the muscles. But why do the muscles move? The answer to

This is just one of the many complicated activities made possible by the human nervous syst

Blair Academy, Blairstown, N. J.

this question may be found in a study of the nervous system.

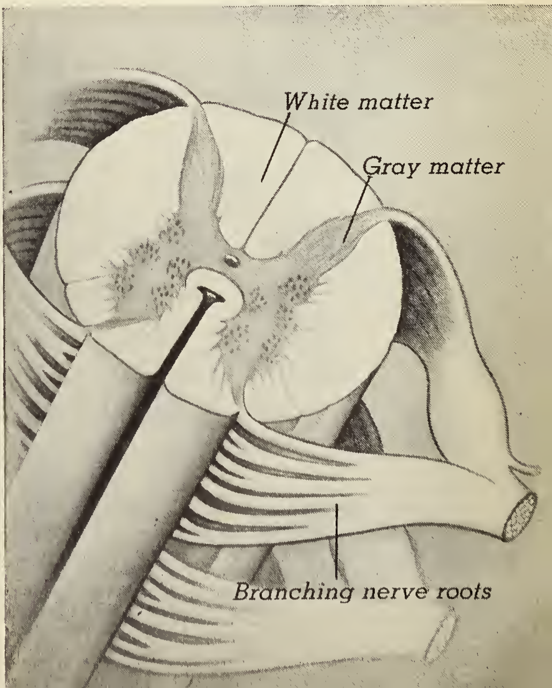
The nervous system is the regulator of all our complicated body machinery, and at the same time is the most wonderful part of that machinery. Its work is so varied and complex that its presence in our bodies makes it impossible to compare them accurately with any other machine. The nervous system consists of two main divisions: the *cerebrospinal* ("cerebro" refers to the brain, and "spinal" to the spinal cord), and the *autonomic* ("auto" comes from a Greek word meaning "acting upon or within itself"). Let us see how these two divisions of the nervous system work.

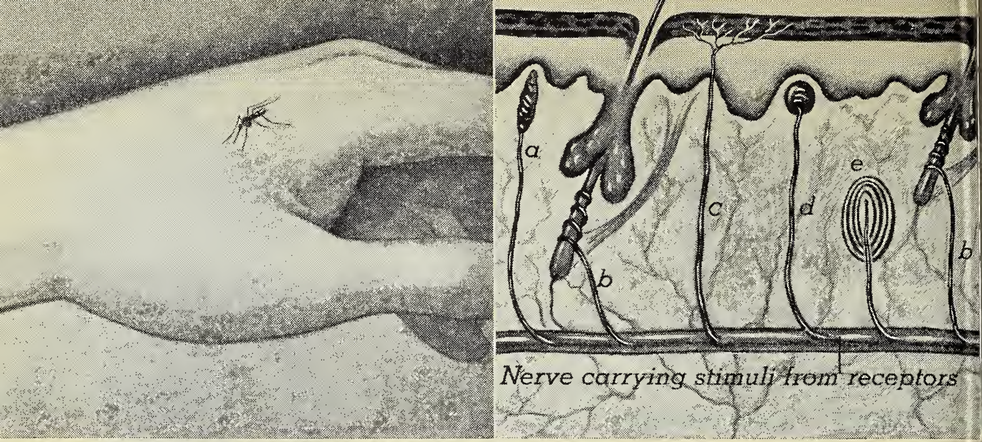


The central nervous system consists of brain, spinal cord, and nerves

Parts of the Cerebrospinal System. The cerebrospinal, or central, nervous system is shown in simplified form in the upper diagram on this page. Notice that it includes the *brain*, the *spinal cord*, and the many *nerves* which run to all parts of the body. You can see that the cerebrospinal system is similar in design to the roots of a tree. The branching rootlets all join the main root of the spinal cord, which in turn connects with the brain.

The spinal cord is like a telephone exchange





The tactile receptors are sensitive to touch through the skin (a), to touch through a hair (b), to pain (c), to heat and cold (d), and to pressure (

The Spinal Cord. If you could look closely at a section of the spinal cord, as shown on page 425, you would see that it consists of a mass of gray and white matter. Close examination would show that the *gray matter* is composed of countless nerve cells, and the *white matter* of stringy nerve fibers. Nerve fibers branch off all along the spinal cord, like the wires of a vast telephone exchange. Through these nerve "wires" messages can be sent and received at almost every point in the human body.

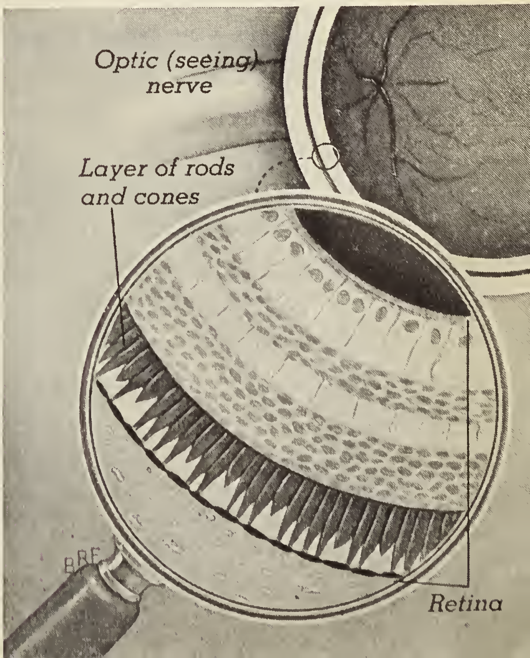
Work of the Receptors. The nerves that compose the cerebrospinal system are those which direct voluntary action. When you turn the pages of this book, for example, your action is directed by this system because turning a page is an intentional, or voluntary, act. But how is this fact accomplished? It is accomplished first of all by the work of certain receiving, or *sense, organs*, which do somewhat the same kind of work that telephone receivers do.

There are millions upon millions of these small sense organs (*receptors*), and they are located in all parts of the body. The receptors are alike in that all are sensitive to some sort of stimulation. They are unlike in that some of them are sensitive to touch, others to light, others to sound, others to smell, and others to taste. Each group is specialized for its own particular work.

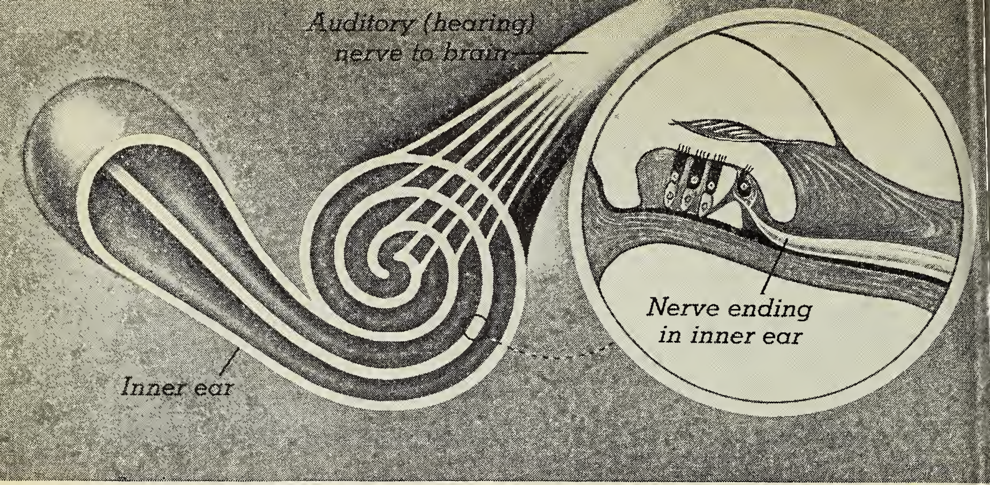
The Receptors for Touch. The touch, or *tactile*, receptors are found in the skin, the muscles, and certain other organs. Within this group of receptors there are different types, as shown in the diagram on the opposite page. One type reacts to pain, another to pressure, another to touch, and still others to heat and cold. These sense organs differ in the extent to which they are sensitive. Some of them, for example, are so sensitive that they react when you merely touch a hair on your arm; others do not react until they are severely pounded.

The Receptors for Vision. The receptors for vision are located in the eye and are sensitive to light. In the last unit you learned that light passes through a lens in the eye which is much like the lens of a camera, and which focuses rays on the retina. The receptors which are sensitive to light are located in the retina. They resemble a mass of rods and cones, as shown in the drawing below. The image is formed on these rods and cones, which are the nerve endings of the *optic* (seeing) *nerve.*

The receptors for vision are in the retina of the eye



We commonly say that the eye is the organ of sight. While this is true, strictly speaking the eye is only the organ which receives the stimulation of light. Sight is the interpretation which is given to this stimulation. The interpretation is made in the



The receptors for hearing are in the inner ear

brain rather than in the eye. Any stimulation of the optic nerve is interpreted by the brain as sight, and stimulation other than light may produce the sensation of light. A severe bump on the head, for example, may stimulate the optic nerve and cause you to "see stars," even if your eyes are closed and no real stars are visible.

The Receptors for Hearing. Sound waves entering the ear pass through a canal to the eardrum, and from there to the inner ear. If you could look closely at the inner ear, you would find a cavity containing liquid, as shown in the illustration above. In this cavity are the tiny receptors that are sensitive to the stimulation produced by sound waves. If you could trace the nerves running from these receptors, you would see them combine to form the large *auditory* (hearing) *nerve.* Like the optic nerve, the auditory nerve runs to the brain, and it is there that the stimulations from the sound waves are interpreted as sound.

The Receptors for Smell. The receptors for smell, as shown on the opposite page, are located in the passages of the nose. They are stimulated by chemical substances which come from the air and are dissolved in the mucus that lines the passages of the nose. The receptors of smell carry the stimulation through a main nerve, called the *olfactory* (smelling) *nerve*, to the brain, where it is interpreted as an odor of one kind or another.

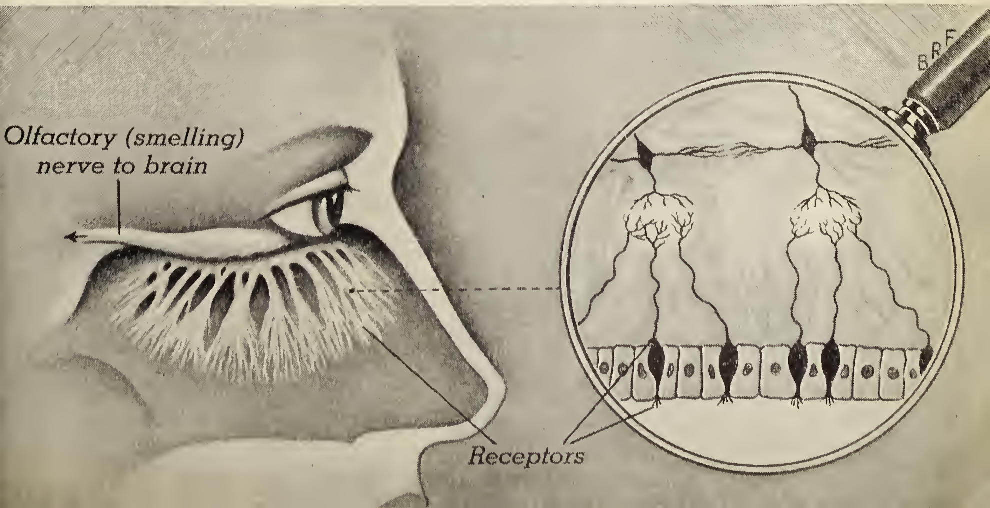
The Receptors for Taste. The receptors for taste are located in the mouth. They are called the *taste buds*, and you may find them on your tongue if you search for them.

Exercise. Explore the surface of your tongue by using a drop of weak vinegar on the end of a toothpick. First touch the top of the tongue well toward the back of your mouth. Do you immediately taste the vinegar? Now wash out your mouth with water and try again. This time touch one side of the tongue. Does this tell you where the taste buds are located?

If you could examine the surface of the tongue very carefully, you would find a great number of crevices containing the taste buds. One of these crevices is shown in the diagram on page 430. The taste buds are sensitive to four kinds of taste: bitter, salt, sweet, and sour. As substances reach the tongue, they pass over the taste buds. The buds react to the substances and carry each particular stimulation to the brain, there to be interpreted as taste.

Sometimes we say that a substance is tasteless. What we mean is that it does not possess any of the four qualities

The receptors for smell are in the passages of the nose



mentioned and therefore cannot be recognized by the taste buds on the tongue. Ordinarily we don't like a tasteless substance. Chalk, for example, is tasteless. It is used extensively as toothpowder, but a flavoring substance is added merely to make it acceptable to our sense of taste.

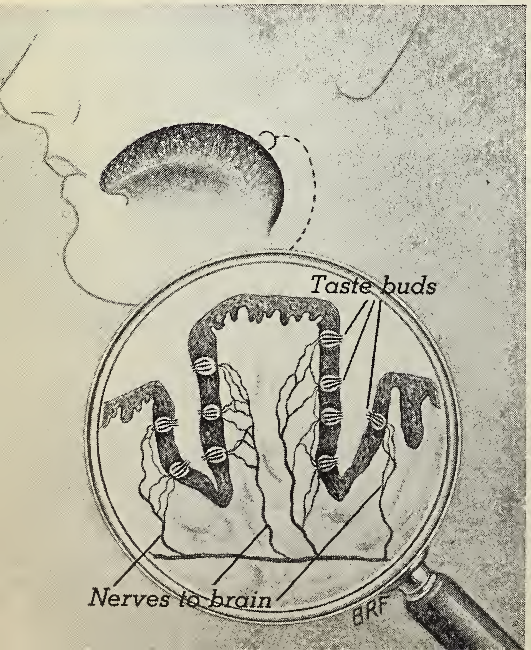
How Impulses from the Sense Organs Reach the Brain. All these different receptors are adapted to their special work. The receptors for smell are not sensitive to pain; the receptors sensitive to pain are not sensitive to taste or smell. A sip of cocoa may taste sweet, but it may also feel hot. In such a case two types of receptors must work at the same time.

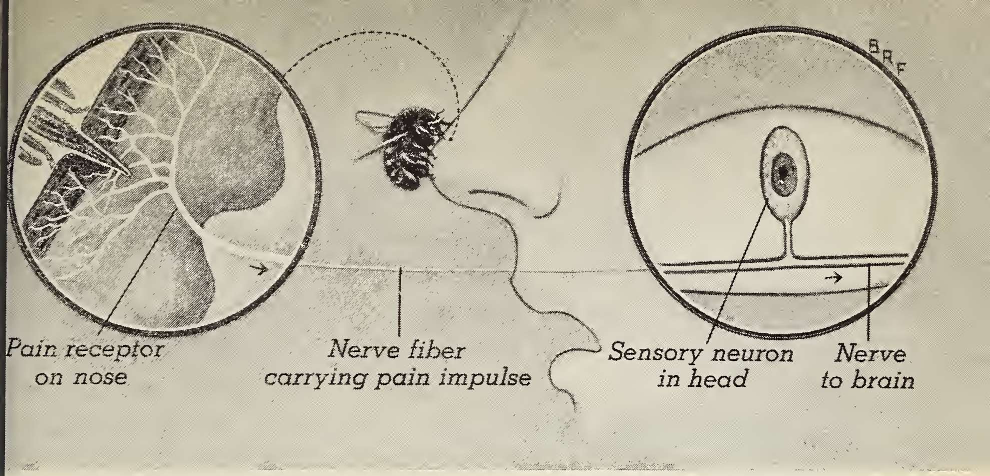
Exercise. Can you think of similar cases where two or more types of receptors must work at once?

We have already said that each receptor, or sense organ, is attached to a nerve which carries the stimulation to the brain. The drawing on the opposite page shows such a nerve. Notice that the *nerve fiber* leads from the receptor (in this case a receptor for pain) to a *neuron*, and thence to the brain. Since this particular kind of neuron helps to carry a stimulation from a sense organ, it is called a *sensory neuron*.

Imagine now that a sense organ has been stimulated in some manner. An impulse travels along the neuron, exciting other near-by fibers

The receptors for taste lie
in crevices of the tongue





ry neurons help to carry sensations from the sense organs to the spinal cord and brain

which are parts of other neurons. In this way impulses are gathered up in all parts of the body and carried to the spinal cord and the brain. The spinal cord and the brain are themselves masses of neurons, called *central neurons*, whose business is to receive impulses from the sensory neurons.

How Impulses from the Sense Organs are Dealt With. What happens after an impulse starts traveling through a sensory neuron? Suppose you are sitting in the living room reading an exciting story. Suddenly you hear your mother call from the next room, asking you to go into the kitchen and take the teapot off the stove. You get up and start for the kitchen, wondering what is going to happen to the hero in the story. Your thought only partly on the job you are doing, you walk into the kitchen and reach absent-mindedly for the teapot.

You have not even thought of the possibility that the teapot may be hot, but you soon discover that it is. You pick it up but suddenly let it drop to the stove, where it breaks. You certainly did not mean to drop it, but the action was automatic. You did not even think about it.

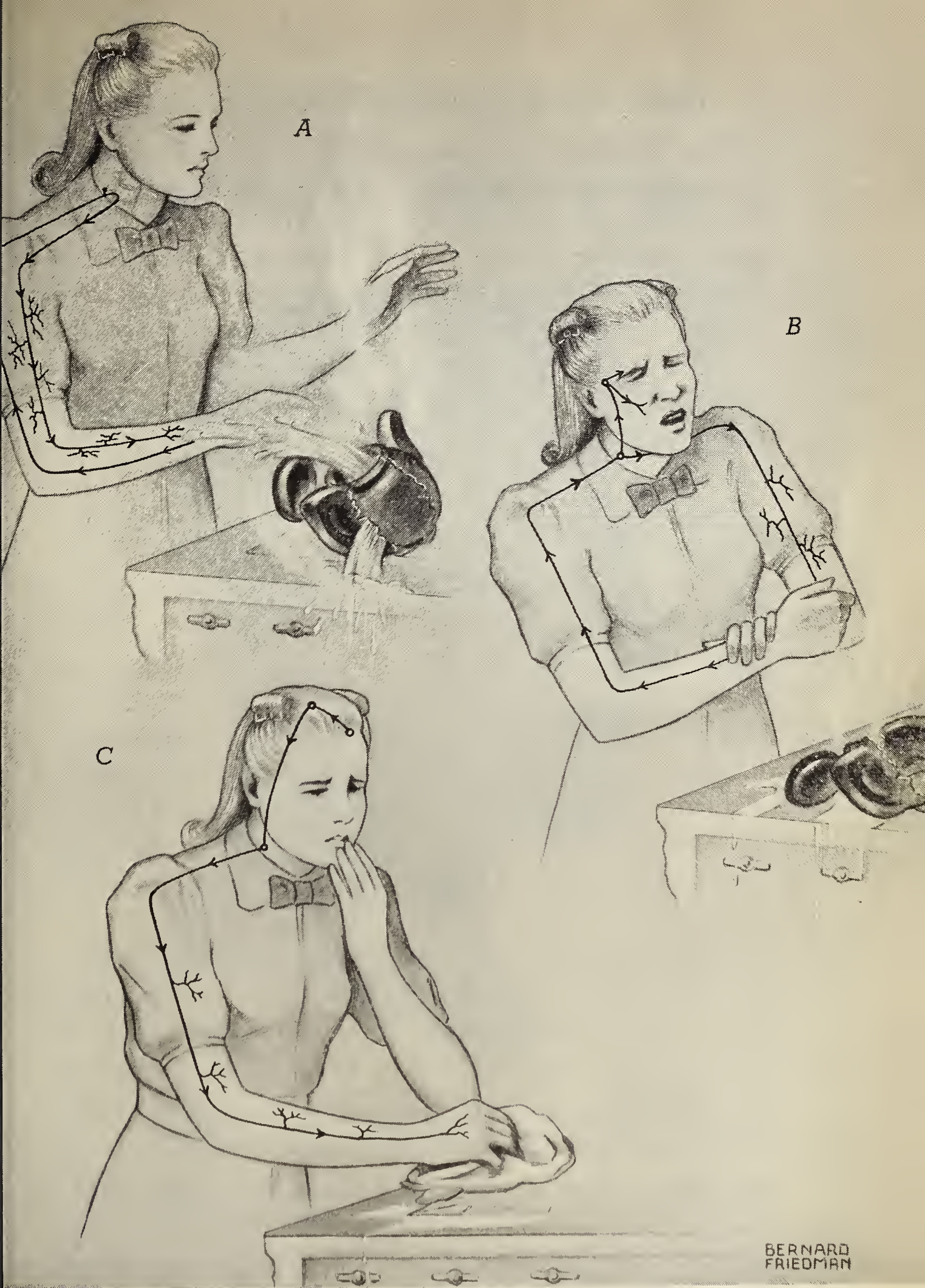
In this particular case a sense organ in your hand received the stimulus from the hot teapot. The impulse was immediately transferred by a sensory neuron to the central nervous system, which passed it on to the muscles. These, in turn, caused you to open your hand and pull it away. Such an automatic response to stimulation is known as a *reflex action*, or a *reaction on the first level.*

Such reactions are very common in our daily lives. We jump when we hear the sudden sound of an exploding automobile tire, and we squint when a bright light strikes our eyes. In all reactions of this sort the impulse travels from the receptor to the spinal cord and from there to the reacting organs, *without passing through the brain.* The illustration on the opposite page shows what happens in the case of the hot teapot.

If after you opened your hand and dropped the teapot you wrinkled your face or shook your hand in pain, you would have experienced a *reaction on the second level.* As the illustration shows, such a reaction is more complex than a reaction on the first level because the nervous impulse passes through the brain.

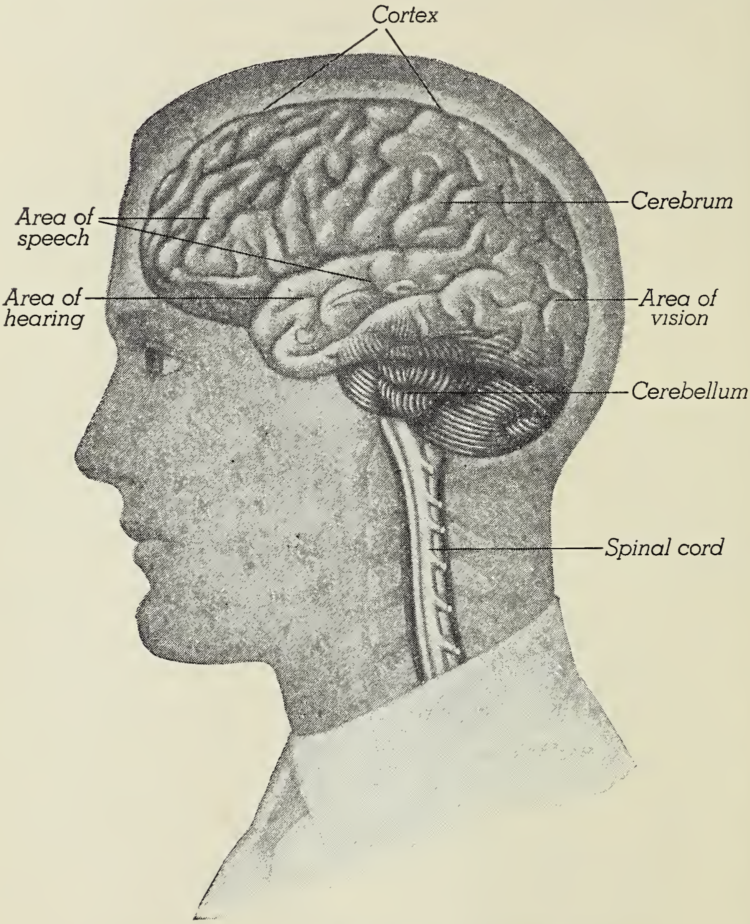
If after the teapot crashed you realized that you had better clean up the mess, you would have experienced reactions on still higher levels. Remembering that the teapot was hot, you picked up the pieces with a hot-dish holder and placed them in the trash barrel. Fearing that your mother would be angry if you did not remove the spilled tea from the stove, you searched for some rags with which to perform this task. Meanwhile you thought of just how you had better explain the accident to your mother.

During all this thinking, planning, and acting your nervous system was at work, as the diagram shows. The centers of reaction were very definitely in your brain, on levels much higher than those at which your unhappy experience with the teapot began.



This little teapot tragedy illustrates how the nervous system works

The Human Brain. Should you say that any one part of the cerebrospinal nervous system is more important than any other? This is a difficult question to answer; but one thing is clear: the great development of the brain is man's most outstanding feature. If you refer to the drawing above while reading the following paragraphs, you will find



Different parts of the brain perform different tasks[1] that all the behavior that requires what we usually refer to as "thought" seems to have its origin in the brain.

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[1] From Andress, Goldberger, Hallock, *Helping the Body in its Work.*

While we usually think of the brain as one organ, you will see from the illustration that there are really several parts. The one with which we are directly concerned now is called the *cerebrum* (the Latin word for "brain"). This in man is far more highly developed than in any of the animals and is a symbol of man's greater intelligence. The outer part of the cerebrum is called the *cortex*. The cortex, a mass of gray matter, is deeply wrinkled, giving the familiar appearance shown in pictures of the brain.

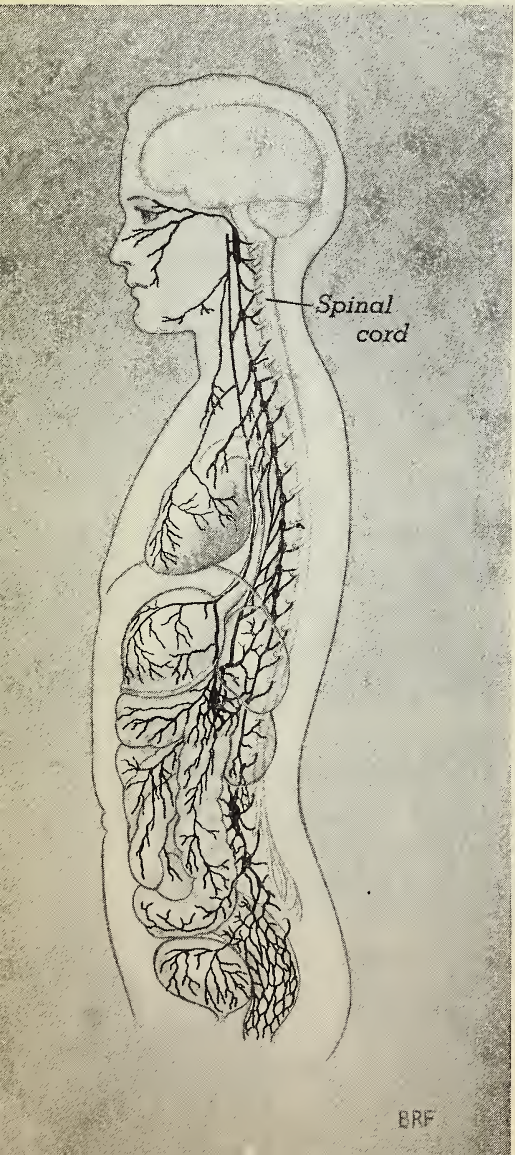
Scientists believe that nerves leading from any one kind of receptor end in a particular area of the cortex. For example, one area forms the center of sight, another the center of hearing. There are certain observations which support this belief. As a result of accidents to a certain area of the cortex, individuals have been made blind. Injury to another area may cause deafness. At the same time the outer organs of sight or hearing may be perfectly normal. Experiments have shown that animals may be deprived of certain senses by destroying certain sections of the cortex.

The Autonomic Nervous System. We have already mentioned the fact that certain organs within the body perform their work without any conscious action on the part of the individual. Among these organs are the intestines, the spleen, the liver, the heart, and the kidneys. All these are under the control of the autonomic nervous system, shown in the drawing on page 436.

Notice that the centers of the autonomic nervous system are not located in the spinal cord but in front of it. From these centers, as you can see in the illustration, the nerves run to various organs of the body. The arrangement and working of these nerves are similar to those of the cerebrospinal system.

The autonomic nervous system controls automatically many of the processes of life. With its help we can pump blood, breathe, and digest food without troubling to think about how it should be done. The autonomic nervous system is not absolutely separate from the cerebrospinal system, because there are nerves that run from the one to the other. Both systems are parts of the same mechanism. This mechanism controls the activities of the human body as a whole, as well as of all its parts, and without any doubt is the greatest wonder of the living world.

The autonomic nervous system (in black) lies in front of the spinal cord



Thought. This book is the product of what we call "thought" in the authors. If it fulfills its purpose, it will produce "thought" in its readers. But what exactly is thought? As a matter of fact, no one really knows, though many guesses have been made.

We do know that through his nervous mechanism man can do many things that are impossible for other creatures. Unlike other creatures whose behavior is almost wholly on the lower levels of reaction, man can use his experiences to improve his lot on earth. It is this ability that enabled him to get control over other creatures and to use them to suit his needs. It is the same ability that enabled him to get control over the forces and materials of his physical environment and to use them in building an ever safer, more comfortable, and more interesting life.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The tendons that hold our bones together are very strong.

2. With age the joints of the body grow stiff and the bones soft.

3. The changes that take place when broken bones heal are the same as the changes of growth, except that healing is slower.

4. Walking is performed with the help of the long, smooth muscles of the calves.

5. If you look at fat meat under a microscope, you can see the stripes which mark all muscles.

6. An oxygen debt is caused by not breathing deeply enough while sleeping.

7. The large vein through which the blood is pumped out of the heart is called the aorta.

8. The business of the plasma is to manufacture hormones.

9. When the white blood cells of a man multiply during illness, we say that the man has anemia.

10. Injury to the tactile receptors of the nervous system may cause blindness.

11. Each type of receptor responds to its own particular kind of stimulation, and no two types ever work together.

12. A reflex action is an involuntary act of the brain.

13. The autonomic nervous system is more important than the cerebrospinal nervous system because it controls our thinking.

14. The human brain is a machine whose operations are completely known through studies on the nervous system.

Questions for Discussion

1. How many examples of the various types of levers can you find in the human body?

2. Consider some common, everyday experiences. You see, for example, a fancy pencil in a store window and then buy it. Can you trace some of the nervous reactions which take place during this process?

3. What evidence would you present in support of the statement that man is more intelligent than animals? Can you think of any happenings that would support an opposite point of view?

Things to Do

1. Make a wall chart or diagram of the heart and lungs, showing how blood circulates through them.

2. Look up records for some athletic event such as the quarter-mile or mile run, and see how man has gradually run these races in faster and faster time. What has made this possible? Is man developing physically, or is he using his physical ability to better advantage?

3. Find some simple mechanical puzzle entirely new to you, such as a pair of bent nails which may be taken apart, or a pair of rings which are linked together. Time yourself in solving the puzzle for the first time, and then time yourself in solving it the second time. Did the problem take less time the second time you did it? If so, try to explain why.

4. Make a list of common reactions on the first and second levels. After each one, explain why you classified it as you did.

CHAPTER FIFTEEN

What Are the Problems of Private Health?

HEALTH PRACTICES OF THE PAST

What Health Is. We have seen that a human being is a complex partnership of different organs working together under the control of the nervous system. We all know that this partnership does not work equally well at all times or in all people. When it works poorly, we say that the person is ill. When it works well, we say that the person is healthy.

The desire for good health has always been present in the human race, but the ability to control many of the causes of ill health is a recent achievement. We like to think of our modern civilization as one in which the principles of health are effectively applied. It is certainly true that with time man has been able to reduce illness, and to find ways of preventing and curing certain diseases which were once considered incurable.

In the earliest historical records there are accounts of methods used to cure the sick. Some of these seem very strange to us today. Some command our very great respect. All bear abundant testimony to the eagerness of man to keep well. Let us look back into history and see some of the things that man has done in his fight against disease. In this way we can gain a better idea of how far we have traveled on the road to better health.

Health Practices of the Early Babylonians. The ancient Babylonians, who lived long before the birth of Christ, brought their sick to the market place, where the unfortunates told their troubles to their fellows. People who had suffered similar ailments told how they had been cured, and the sick person selected from what he was told the treatment he wished to take. Perhaps this does not seem so ancient after all. The conversations in the ancient Babylonian market places must have been similar to many conversations of today, for people still like to tell of their ailments and what they did or are doing to cure them.

With the Babylonians, however, as with other ancient peoples, cures were sought very largely through charms, religious ceremonies, and drugs. These people also indulged widely in the vicious practice of bloodletting, a process in which blood was taken from the body in the belief that "bad blood" caused illness and therefore should be removed.

Though bloodletting today seems a better way of killing than curing a patient, not all ancient practices were contrary to the findings of modern science. The early Babylonians used hot and cold baths in their treatments of the sick, a practice that is still favorably regarded by many modern physicians. They also used salves and oils, as we do today, to massage the parts of the body in which pain is felt.

Health Practices of the Early Greeks. Among the early Greeks the name of Aesculapius is associated with the treatment of disease. According to Greek myths Aesculapius was educated by a centaur named Chiron, half man and half horse. He was taught the healing effects of herbs and was said to have gained such great power in the treatment of disease that he was able to bring the dead to life.

Temples were erected to this god of medicine, and they

The legend of Aesculapius, Greek god of medicine,
was the basis of many ancient healing practic

served as places of worship as well as places for the treatment of the sick. The patient was received at the temple by a priest who performed certain ceremonies, generally the sacrifice of a rooster or a ram. The sick man would then sleep in the temple. He believed that if he were sufficiently earnest and reverent, Aesculapius would appear to him in a dream and tell him what to do to become well.

The priest of the temple then interpreted the dream and directed the treatment. Interestingly enough, the treatment was often of the kind commonly recognized today as best for most ailments. It included good food, rest, massage, bathing, sunshine, and fresh air. Some drugs were known, and used when the condition of the patient seemed to require them. Those who recovered from illness left as an offering to the god a tablet of stone giving the history and treatment of the disease. Such tablets were prominently displayed in the temple. Perhaps the Greeks followed certain modern methods of advertising, for no records were kept of those who failed to obtain a cure.

It is easy to imagine the mental effects that might have come from the display of these testimonials. The incoming patients were surrounded by accounts of marvelous cures, belief in which must certainly have had a wholesome influence upon the new patients. Together with good food, sunshine, fresh air, and other means employed in treatment, such belief must have helped to make these ancient temples fairly effective hospitals. At any rate, they were prominent in the history of Greece and neighboring countries for more than a thousand years.

Health Practices of the American Indian. The American Indian, like other primitive peoples, used strange religious ceremonies in the treatment of their sick. In one tribe the priest-physician, dressed in a costume similar to that shown on page 444, used rattles, feathers, eagle claws, and the feet of animals in the attempt to drive out the evil spirit of illness. The religious ceremony was strengthened by other treatments, including the use of herbs and sweat baths.

From this brief account you may properly conclude that health has always been a matter of interest to people, and that all people have attempted in one way or other to cure disease. Though they arrived by accident at some rather effective health measures, they had little real knowledge of the workings of the human body either in health or in illness until science took the place of superstition.

Exercise. Do you believe that people today are still superstitious about health? Make a list of modern health superstitions and explain why you think each one is a superstition rather than scientific knowledge.

THE EFFECTS OF PARASITES ON HEALTH

The Problem of Germ Diseases. You have already seen that good health depends on the smooth working of the partnership between the different organs of the body. Let us now consider the ways in which this working is disturbed so that the condition of illness, or disease, results. High among the causes of disease is the invasion of the body by certain extremely small plants and animals called *germs*.

This Indian medicine man believes that disease is an evil spirit which can be driven away by secret

Great Northern Railway

Typhoid, malaria, and diphtheria germs are small but mighty

The bodies of all living creatures are made up of tiny units of living matter called *cells*. So small are these cells, for the most part, that several hundred of them together are just barely visible to the naked eye. The body of an ordinary germ is made up of only one cell. The picture above shows how some of these one-celled germs appear under the microscope.

You may remember that in Chapter Three we studied the problem of disease in domesticated animals and found that it centered round the problem of controlling parasites. *Parasites are plants or animals that live at the expense of other plants or animals without paying in any way for what they receive.* Men too are subject to parasites, most of which are bacteria (one-celled plants) or protozoans (one-celled animals). Let us see what these unwelcome visitors can do to our health.

The Problem of Malaria. Fortunately, most of them are harmless. A few, however, are extremely harmful, and among these the malaria germ is one of the worst. This germ is a tiny protozoan which is carried from one person to another by a certain kind of mosquito. It has a peculiar life history, because part of its life must be spent in the body of a mosquito and part in the body of a human being. Because of this fact the malaria parasite may not pass directly from one person to another or from one mosquito to another. It can pass from man to man only by way of a

This is how malaria is spread

mosquito, and from mosquito to mosquito only by way of a human being, as shown above.

In the blood stream of a human being the malaria parasite attacks and feeds upon the red corpuscles. The destruction of red corpuscles and the presence of waste products by this destruction cause the symptoms of the disease. Without enough red blood cells to carry oxygen to the body, anemia results and the entire body is severely weakened.

Control of malaria is achieved by destroying all mosquitoes of the kind that carry the malaria germ. By draining swamps where the mosquitoes breed, by removing all objects that might hold stagnant water in towns and villages, and in other ways, the curse of this disease has been greatly reduced. In some communities where malaria was once a common illness it is now practically unknown.

The Problem of Yellow Fever. Some of the most interesting stories in the history of man's fight against disease have to do with his life in the tropics. At the time of the Spanish-American War (1898) our soldiers in Cuba suffered a great deal from yellow fever. No one knew how the disease was carried. It was believed that it was contagious, that one person could give the disease to another by mere contact.

Directly after the war army physicians began working on the problem. With the aid of volunteers, some of whom died in the experiment, it was found that yellow fever, like malaria, is carried by a certain kind of mosquito. To prove

Hansel Mieth from *Life* Magazine

ellow-fever mosquitoes that steal rides on planes
must pay for their passage with their lives

the cause of this illness, one of the suspected mosquitoes was allowed to suck the blood from a person suffering from yellow fever. A little later the same mosquito was allowed to bite a healthy person. This person, a private soldier who had volunteered for the test, contracted the disease.

As a result of this heroic experiment and many observations, a drive was made to clean up the breeding places of the yellow-fever mosquito. This has now been done so well that yellow fever is practically unknown today in North America. Such former hotbeds of the disease as Cuba and the Canal Zone are now almost entirely free from it.

Exercise. Read in De Kruif's *Microbe Hunters* the exciting stories of the conquest of malaria and yellow fever. Report on them in class.

The Problem of Diphtheria. The one-celled plants (bacteria) cause a greater variety of diseases in man than do the one-celled animals. Among the diseases known to be caused by bacteria are diphtheria, typhoid fever, tuberculosis, tetanus, and plague. The story of the conquest of diphtheria, once the deadliest of all children's diseases, is one of the most glorious chapters in the history of modern science.

Diphtheria, a highly contagious disease, is caused by bacteria that may live in the human throat. It is easy to understand how this illness is spread. A sufferer from the disease may hurl little droplets of moisture from the throat by coughing or talking. Bacteria may be carried with these droplets into the air, and into the throat of another person as he breathes. Fortunately these bacteria will remain alive in the air for only a very short time; one therefore can hardly "catch" the disease unless very close to a person who has it.

Since the diphtheria germs live in the throat, they feed on the mucus secreted there. Waste products are formed while the germs are growing, and among them is a substance called *toxin* ("poison"). This poisonous substance passes into the blood and causes the symptoms of the disease.

You have already learned that one function of the blood is to resist the effects of poison. Through this activity of the blood every person seems to have some power of resistance against disease. As the diphtheria bacteria grow in the throat and release toxin into the blood, the body fights the poison by developing a substance which has been called *antitoxin* ("against poison"). With the help of this natural defense a patient may recover from the disease without any other aid.

Some people seem to be entirely immune to diphtheria; others may have it in such a light form that they are hardly conscious of any illness at all. All too often in the past, however, the disease has resulted in painful suffering and death. In fighting diphtheria scientists had observed many times that most of those who once had the disease did not get it again. One illness made them immune. In the search for a treatment for diphtheria, a method was sought that would produce in the blood of a patient who had never had the disease the same effects that were produced in the blood of a patient who had had it and got well. In other words, an artificial immunity was sought.

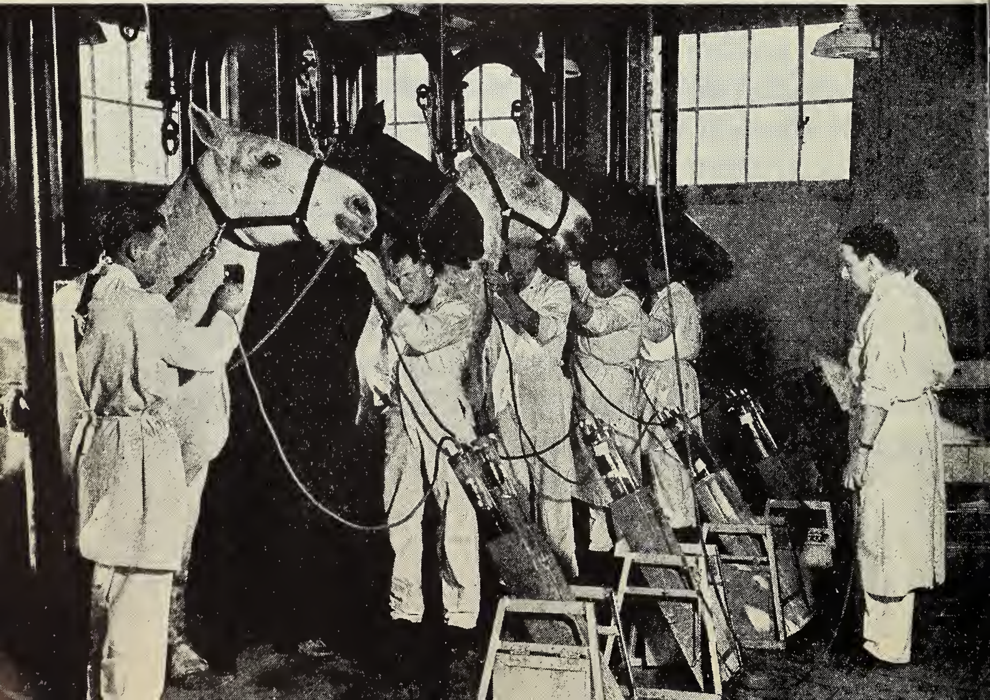
Working along this line, scientists found that there normally is a small amount of antitoxin in the blood. As the disease advances, the amount of antitoxin increases. Unfortunately, however, it may not increase fast enough to save the life of the sufferer. Scientists found that if additional antitoxin was injected into the blood, the danger of death from diphtheria was very slight.

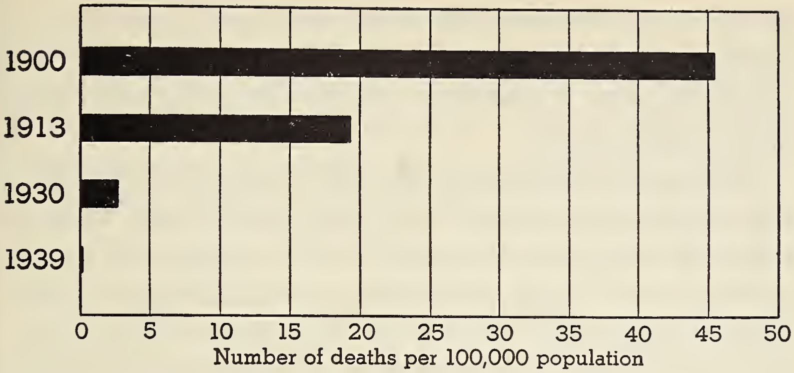
After making this great discovery it was next necessary to find some way of providing the additional antitoxin in quantity large enough for use. This problem was really much simpler than you might suspect. The bacteria that cause diphtheria may be grown in a test tube, and diphtheria toxin may be produced there just as in the throat. The toxin may then be dissolved in liquid. Diphtheria bacteria are very tiny, but with an extremely fine filter the liquid containing the toxin may be filtered from the tiny germs that produced it.

Now suppose that some of this liquid is injected into an animal, say a horse. Will the horse have diphtheria? The answer, of course, is No. There are no bacteria in the toxin, and only the bacteria can cause the disease. The horse, however, may suffer somewhat from the effects of the poisonous toxin but not enough to cause him any great or serious discomfort.

Diphtheria antitoxin developed in the blood of horses has saved the lives of many children without any harm to the hors

Life Magazine





This graph, based on health records of New York State, shows how modern science has triumphed over the dread diphtheria

The blood of the horse resists the effects of the toxin by developing antitoxin. In practice, a small dose of germ-free toxin is injected into the blood stream of a horse. Some antitoxin immediately forms to resist the effects of the poison. In a few days a second dose of toxin, larger than the first, is injected, and more antitoxin is produced. The treatment is continued with increasing doses until the horse is able to take and resist a very large amount of toxin.

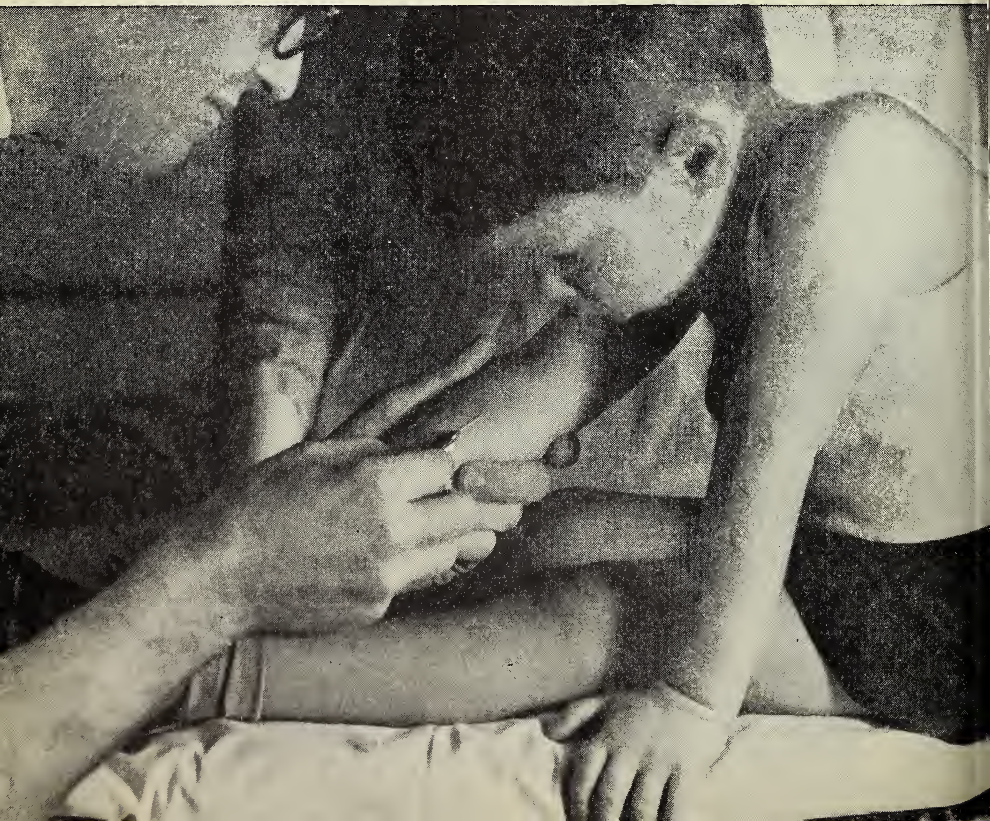
In time the blood of the horse contains a large amount of antitoxin. Since the horse is a large animal, a considerable quantity of blood may be drawn from its body without harm. Antitoxin may be separated from this blood and used to save the lives of children after they have contracted diphtheria. One step in the production of antitoxin is shown on the opposite page.

A few years ago a treatment known as the *toxin-antitoxin treatment* was discovered for developing immunity from diphtheria. By this method antitoxin is produced in a person instead of a horse. A mixture of toxin and antitoxin is injected into the body; the antitoxin balances the effects of the toxin, and the toxin brings about the production of more antitoxin. When this is produced in the blood, the person acquires a protection similar to that produced by having the disease.

Antitoxin for diphtheria was first developed about 1890. The reduction in deaths from this disease since 1900 is shown in the graph on page 451. No doubt the use of antitoxin has largely contributed to this decrease. Many successful men and women are alive and working today who would have died in childhood had not the antitoxin treatment been discovered. There is still some diphtheria in the world, but if the modern toxin-antitoxin treatment were given to all children this disease could be completely wiped out.

The toxin-antitoxin treatment is a safe and certain means of developing immunity from diphtheria

Rothstein from U. S. Public Health Service



Control of Other Germ Diseases. Other antitoxins have been developed by application of principles similar to those that led to the production of antitoxin for diphtheria. There are effective antitoxins for tetanus (lockjaw), hydrophobia, and snake bite. Each of these diseases is extremely dangerous if the antitoxin is not used, but there is almost no danger of death from any of them if the antitoxins are properly and promptly applied.

Still other bacterial diseases have been brought under control by somewhat similar methods. In general, all treatment for such diseases is based on the knowledge that the normal ability of the blood to resist invading bacteria can be strengthened. To develop immunity from typhoid fever, for example, dead bacteria are injected beneath the skin. These act similarly to the toxin of diphtheria and produce, without causing the disease, a protection similar to that which is produced by actually having it. Similarly, vaccination against smallpox causes a mild and harmless form of the disease and bestows an immunity which is protection against further attack from this particularly ugly ailment.

Exercise. Find out from the health authorities of your community what children's diseases may be effectively treated by antitoxins or similar methods. Make a report to your class on the diseases that may be so treated, and describe the nature of the treatment in each case.

The Larger Parasites. Not all parasites that produce disease in man are tiny one-celled germs. A considerable variety of larger parasites may find it agreeable to board and room with us. Consider the hookworm whose family portrait appears on page 454. It may live as a parasite in man by attaching itself to the walls of the intestine. Its activities there result in the loss of considerable blood by its victim. All sufferers from hookworm disease are anemic and consequently very low in physical endurance.

This disease is common in warm regions where people go barefooted. The parasite commonly enters the body of a victim through the skin between the toes. Once in the blood, hookworms may be carried by the blood to the lungs. Here they penetrate the air sacs and enter the breathing passages. They may be coughed up from the lungs and swallowed, after which they reach their lodging place in the intestine. The disease may be cured by treatment with drugs, and prevented by cleanliness. It is a filth disease which is passed from person to person through the waste materials of the body and develops under conditions like those shown on the opposite page. It cannot develop if sewage is properly disposed of.

Exercise. Look up and report on the prevention and cure of other diseases which worms produce in man.

Hookworms live in the human intestines

The Rockefeller Foundation

Private and Public Warfare against Disease. Though we have discussed the diseases which are produced by germs and other parasites in this chapter on private health, some of the most effective measures against these diseases have been achieved in the field of public health. Private attacks on parasites through the use of antitoxins and similar weapons have been greatly strengthened by public attacks through such means as proper sanitation. So important is the public warfare against disease that we shall devote the entire next chapter to its consideration. In that chapter you will learn some more about parasites.

OUR HABITS AND OUR HEALTH

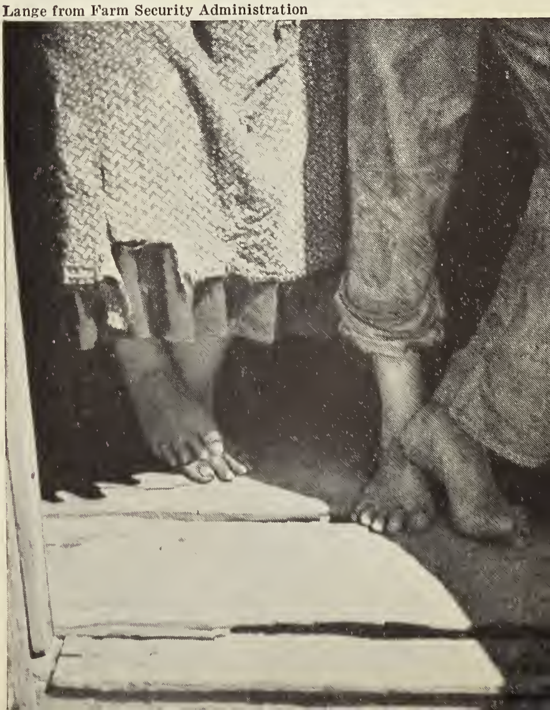
Unconquered Diseases. Though many diseases have fallen before the advancing army of scientific investigation, many others remain. In some of these the causes are not yet known. In others the causes are known, but man has not been able to find wholly effective means of fighting them. Thus, while man has discovered the bacteria which are responsible for tuberculosis, he has not been able to develop an antitoxin which will control them.

Many people believe that this disease may be cured by drugs. They waste millions of dollars a year on treatments which are nothing but cruel fakes. So far, the only cure for tuberculosis has been found in rest, fresh air, sunshine, and good food. This treatment is fortunately often effective; if the "rest cure" is begun before the disease has run too far, recovery may be complete.

Even some apparently simple diseases are yet a mystery to science. The common cold is an example. We know that it is conta-

Going barefooted in warm regions is an invitation to hookworms

Lange from Farm Security Administration



Paul Parker from Girl Scouts, Inc.

Some of the best medicine does not come in bottles

gious, but no one has found the germ responsible for it —if indeed a germ *is* responsible. As we look upon the record of successes in control over other diseases, such as malaria, typhoid fever, diphtheria, and yellow fever, it seems safe to predict that some day the mysteries of even the dreaded tuberculosis and the less-dreaded common cold will be solved. Meanwhile, what can we do to protect ourselves against the unconquered diseases?

Shall We Take Medicines? The common method of treating illness is to take medicines. This treatment was used by primitive men as far back as one can trace history. It is often used today with no more intelligence than in earlier days. In the course of time certain substances have been found which will produce certain well-known effects on the human body. There are drugs that kill pain, drugs that move the bowels, and other drugs that act as stimulants. But since the cause of all illness is some disturbance of the normal functioning of the body, *most medicines treat the effects without touching the causes of disease.*

Our great faith in medicines, handed down to us from our forefathers, finds little support from modern science. Its chief value is the help it gives to dishonest advertisers who lead innocent people into taking worthless, sometimes dangerous, and always expensive medicines for their discomforts.

Exercise. Look through some magazines and newspapers and see how many advertisements appear which claim that certain products have value as medicine. Check radio programs for a week and see how many so-called "remedies" are advertised there. To what extent do you believe these advertisements dishonest?

Alcohol, for example, is a typical narcotic ("stupor-producing") drug. When taken in small quantities, it slows down the normal functioning of the body. In large amounts it produces complete unconsciousness and sometimes death. The effects of alcohol in small and large amounts have been carefully studied, and there is very little that can be said to support its use. A typist works

This patent-medicine salesman lives on the blind faith in the power of medicine which many people still possess

Galloway

more slowly and with less accuracy after drinking alcohol; a rifle-shooter is less sure in his aim; a bookkeeper is less accurate in adding a column of figures.

Similarly, it has been shown that ability to memorize and to reason is reduced while a person is even to a small extent under the influence of alcohol. There seems to be no scientific support for the belief that alcohol improves the ability to think. There are stories of great works in literature and music that have been produced by artists while under the influence of alcohol. It seems likely that most of these stories are not true. There can be no doubt that alcohol disturbs the natural operations of the body, and that the effect in most cases is to reduce efficiency.

Alcohol has been used extensively in medicines. In fact, it has in the past been a favorite household remedy and has been used as a "tonic" in the treatment of most of the common ailments. Careful studies show that it is actually harmful in most of the cases in which it has been used. Physicians of today have very little use for alcohol in the internal treatment of disease.

Some drugs and medicines, of course, do have their place in the treatment of disease. Quinine, for example, is a cure for malaria because it acts as a poison to the tiny parasites that feed on the red-blood corpuscles. Chaulmoogra oil is of use in the treatment of leprosy. Other medicines will clear the intestine of tapeworms and hookworms. Such remedies, however, should be used only on the advice of a physician.

Because there are these and other medicines that serve some purposes other than the mere enrichment of their manufacturer, it is impossible to say simply, Do not take medicines. All depends on circumstances. There may be times when a stimulant is needed. There may be other times when other kinds of drugs are needed. But if you want to avoid making your illness worse, and possibly very much worse, let your physician prescribe the medicine.

The Problem of Healthful Living. If medicine is not a generally reliable cure for disease, what is? The answer is so obvious that it may seem silly. *The best way to avoid disease is to remain healthy.* The human body tends to be and to remain in a condition of health if it is treated properly. The rules of healthful living are so simple that they are frequently overlooked. Most important of these rules are the rules of proper eating.

Once upon a time, as you have read in the early part of this book, man's diet presented a comparatively simple problem. As someone has put it, the only problem was whether he ate or did not eat. As the result of much work over many years man today is able to choose from a variety of foods. An attempt to order a meal from a restaurant menu or even to purchase wisely from the neighborhood stores raises many problems.

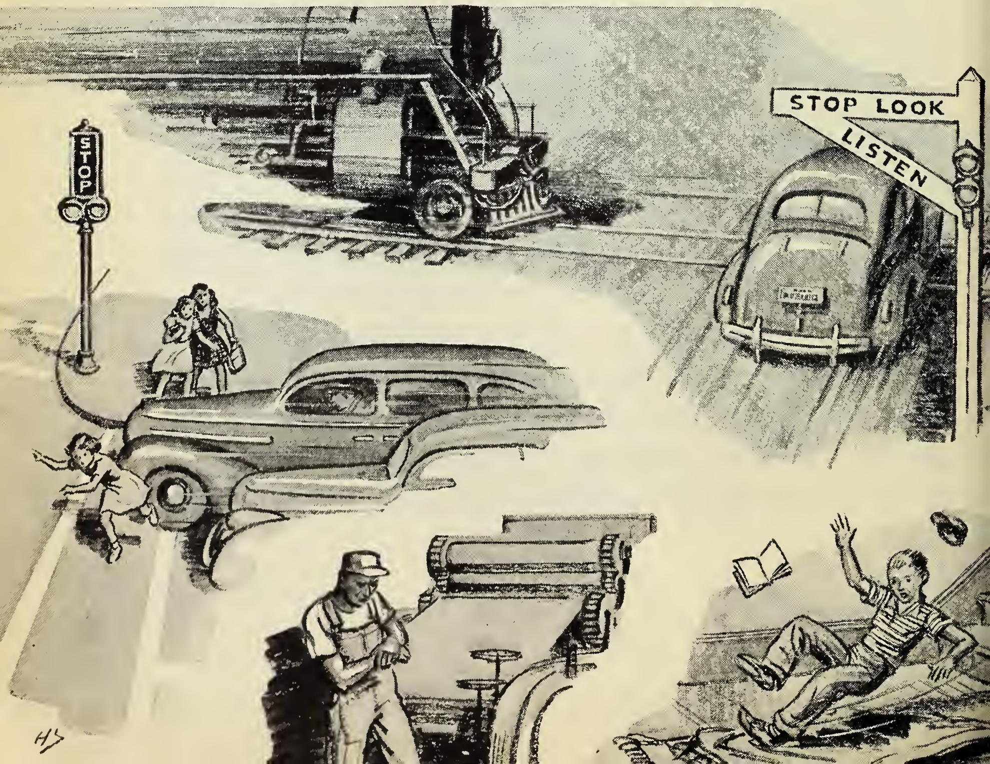
These problems are tied up with knowledge of diets and their effect on the human body. Appetite alone is not a safe guide to proper eating. You know from earlier work in science that certain types and combinations of foods are necessary for good health. You know that certain types of foods may lead to poor health. It is therefore necessary for you to develop eating habits that will safeguard your general health—and youth is the best time to do it.

A plentiful supply of fresh air, sunshine, and exercise was once the least of man's worries, but today our lives are different. Many people live and work in overheated and poorly ventilated buildings. They get neither enough exercise nor enough rest. When their health breaks down, they hope that physicians can do for them what nature would have done had they taken the trouble to give her half a chance. Problems of proper living are largely a matter of private decision. *People today rather generally know the rules of health, but in many cases lack the will power to enforce them.*

With the increasingly complex nature of civilization has come a need for greater and greater alertness. Almost a hundred thousand people a year die as the result of accidents—many more than from diphtheria, typhoid fever, and malaria combined. Why should this be? Part of the answer, of course, lies in the increasing use of machines. Automobiles, industrial machines, railroad trains, airplanes—all contribute to this death rate. But as one examines the causes of accidental death, one is struck with the fact that a great percentage of it is due to individual carelessness.

Consider the accidents illustrated below. An adult drives

Individual carelessness is the cause of most accidents



a car across a railroad track without heeding the stop-look-listen signal. A child is a few minutes late for school and dashes across the street against a red light. An industrial worker goes to bed late; next morning his nervous reactions are slowed down so that a piece of machinery catches his hand. These things are difficult to prevent by public means. The responsibility largely belongs to the private individual.

Exercise. How well do you accept your responsibility to be alert? What unnecessary chances have you taken within the last few weeks?

Finally we come to one of the most important causes of ill health: the refusal of the individual to take advantage of scientific knowledge. Good health depends to a great degree upon the intelligent use of such knowledge. Science has shown how a healthy body works, how its working may be disturbed, and in many cases how the disturbance may be corrected. If the private individual uses good sense in caring for his body, good health will almost certainly be the reward. Is it necessary to add that this reward is well worth having?

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Only with the coming of modern civilization did man take any interest in his health.

2. The bloodletting practice of the early Babylonians was their only sound contribution to the science of curing illness.

3. Though the early Greeks made many fine contributions to art and literature, they contributed only superstitions to the problem of treating disease.

4. All parasites are harmful to their victims and some are deadly.

5. The bacteria that cause malaria feed on the white corpuscles of the blood.

6. Mosquito netting is the only defense against yellow fever.

7. The antitoxin that develops in the blood of a person suffering from diphtheria may be a deadly poison to the sufferer.

8. The toxin-antitoxin treatment for diphtheria saves human life but endangers the lives of the horses that make it possible.

9. Hookworms are bacteria that live in impure drinking water.

10. All medicines are fakes which help only the people who sell them.

11. If a person gets enough fresh air and exercise, he can eat anything he desires.

12. When everything is considered, good health is largely a matter of good luck.

Questions for Discussion

1. How would you define a really healthy human being?

2. Would you agree or disagree with someone who said that man still practices many of the healing arts today which were common thousands of years ago?

3. Do you think that the process by which antitoxin is produced from healthy animals is a cruel one?

4. Could we get along without medicines?

Things to Do

1. See what you can find out about the life and work of some health workers such as Robert Koch, Lord Lister, Hideyo Noguchi, Edward Trudeau, and William Gorgas. Write short sketches of their lives.

2. Make a list of medicines known to have real value as cures.

3. Make a special study of accidents in your community. Which are the most common? What can be done to cut down this accident rate? How does the accident rate of today compare with that of ten years ago?

4. Look up the rules of individual hygiene given in *How to Live*, by Fisher and Emerson, and report on them in class.

CHAPTER SIXTEEN

What Are the Problems of Public Health?

THE PROBLEMS OF BRINGING GOOD FOOD TO MARKET

Need for Public-Health Measures. In studying the problems of health in the last chapter we caught glimpses of diseases which men as single individuals are powerless to combat. It is not enough for man as an individual to care for his private health. Men as groups of individuals have problems of public health, and it is these problems that we shall consider in this chapter.

How well do you know your own community? Do you have the facts which would enable you to answer satisfactorily the following questions?

How well does your community control contagious diseases?
What rules and regulations does it have for the protection of water and food supplies?
How does it deal with the menace of factory smoke?
How sanitary are its methods for disposing of garbage and sewage?
Does it maintain laboratories in which studies and experiments are carried on to further health protection?
Does it spend any money for the health training of its citizens?
How does it compare with other communities in its death and illness rates?

Galloway

Bad housing and bad health go together

Good housing and good health go together

U. S. Housing Authority

PROBLEMS OF PUBLIC HEALTH

In matters of health we depend in many ways on the community in which we live. If we live in a city, we do not know where most of our food comes from or the conditions under which it was produced. As individuals we cannot control the water supply, nor can we properly attend to the disposal of garbage and sewage. These and many similar problems are not the concern of individuals working alone, but of the individuals of a community working together.

Because of this, nearly every community maintains a board of health. We depend on the members of such a board to use the authority of law in the enforcement of such measures as are necessary for the protection of our health. As individuals, of course, we may and should co-operate in this work. It is the right and the duty of every person to demand that public-health officers live up to their responsibilities. Let us see, then, just what these responsibilities are.

Public health demands that meat be kept clean and cool

Galloway

F. M. N. H.

oolly mammoths (left) once roamed the frozen plains of Siberia. The flesh of this mammoth (right) was preserved by freezing for fifty thousand years[1]

How Our Meat Supply Is Protected. One of the most important of all public-health requirements is that the food we buy be clean. When you visit a meat market, for example, you can soon discover whether the public-health officers have done their work well. Is the meat displayed under glass, as shown on the opposite page, so that flies and careless customers cannot touch it? Do cooling coils extend through the case to keep the meat from spoiling? Perhaps the butcher will let you look into his storage room. Do you find this room clean and cool enough to protect its perishable contents?

Exercise. Make a study of the meat market that supplies your family with meat. Does it seem to be practicing the necessary measures of public health? If not, where does it seem to fall short? What can you do about improving the conditions there?

The problems of preserving flesh foods are not simple. Conditions satisfactory for beef, for example, are not satisfactory for fish, because fish must be kept much colder. Oysters, clams, and other sea foods must have particular care. Scientific studies have been made to determine the conditions under which meats and other foods should be kept. Regular inspection by a health officer should guarantee that these conditions are maintained.

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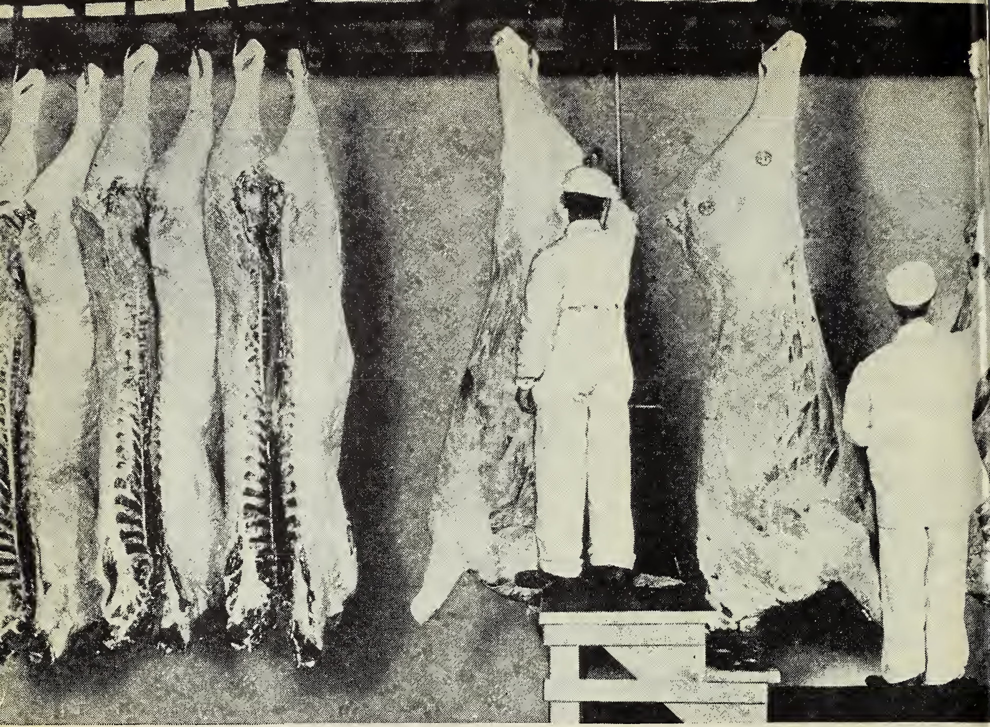
[1] Reprinted by permission from *Outlines of Historical Geology* by Schuchert and Dunbar, published by John Wiley & Sons, Inc.



U. S. D. A., Bureau of Animal Industry

Government inspectors determine what meat is fit to eat

Meat left exposed to warm temperatures very soon spoils, chiefly because of the action of bacteria, yeasts, and molds. Many of these small plant forms develop from tiny spores which are carried in the air. They may settle and feed on meat, thus causing it to spoil. As it spoils, poisonous substances with foul odors are produced. Dangerous results may follow the eating of spoiled meat. At the temperature of properly regulated storage rooms, however, these plants do not grow, and the meat remains fresh indefinitely. Do you see, then, why flesh foods must be kept cool?

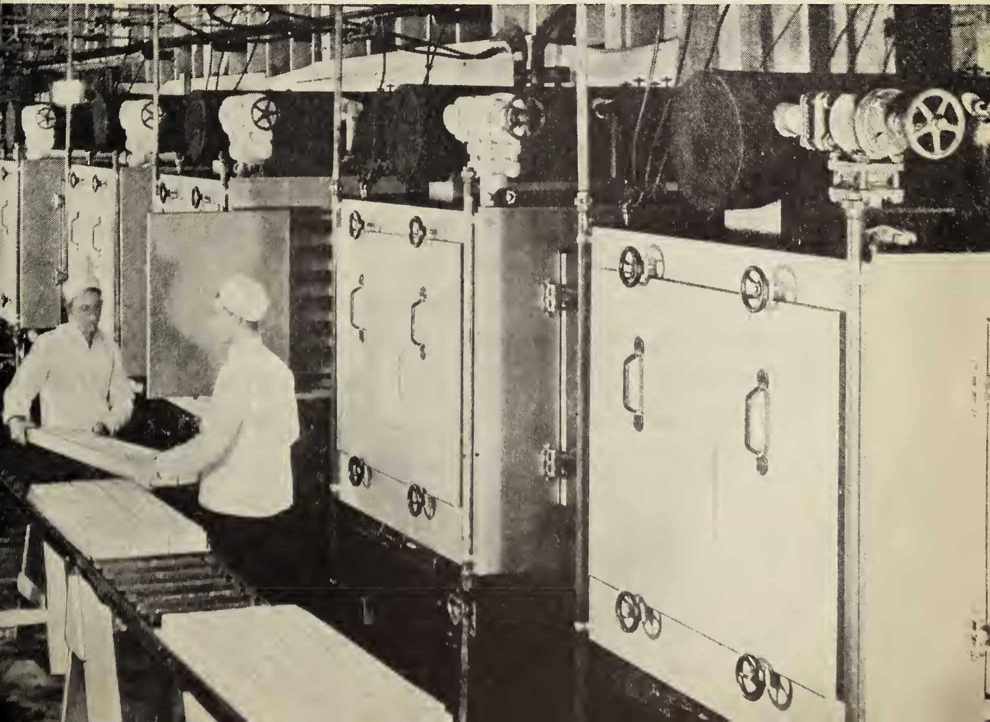
Striking observations on the effectiveness of cold in preserving meats have been made in the discovery of animals found frozen in the ice of the Far North. The photograph on page 467 shows the flesh of a Siberian mammoth, a beast that is now extinct. This particular specimen was frozen to death some fifty thousand years ago. Yet because of the marvelous preserving power of cold, its flesh remained as sweet and clean as when the animal died.

The work of the health officials begins long before meat reaches the market. If you examine the beef, pork, and mutton hanging in the storage room of a modern meat market, you will see that each is plainly stamped "U. S. Inspected and Passed." This means that a government inspector was at hand to see that the animals to be butchered were in a healthy condition.

Beef cattle are inspected especially for tuberculosis. Pork is inspected for the worms which sometimes take up residence in the muscles of pigs, and which cause the disease trichinosis in people who eat the muscles. After inspection the bodies of diseased animals are removed and burned. Only the meat that the inspector finally stamps is fit to eat.

his plant peas and other vegetables are prepared for the market by the new method of quick freezing

Birds Eye Foods



In the slaughterhouses certain standards of sanitation must be maintained. The health officers must grant permits before the buildings can be used at all. Other standards apply to such features as lighting, plumbing, washrooms for workers, and many other things. Every precaution is taken to guarantee that the meat which comes to your table is clean and healthful.

This government inspection is absolutely necessary for our protection. Since it is expensive to maintain sanitary measures, dishonest dealers concerned only with profits would be tempted to use unsanitary methods if the government closed its eyes. Chemicals, for example, could be used to preserve the meat. In appearance such meat might seem wholesome enough, but it might actually be very dangerous to public health. That is why government inspectors do not permit the use of chemical preservatives except under carefully controlled conditions.

How Canned Foods Are Protected. Let us look at some other sources of food. In the grocery store you find fresh vegetables, bread, pastries, and a great variety of canned goods. Why are so many foodstuffs sealed in cans? Obviously, it is to protect them against the action of bacteria. Take tomatoes, for example. Only the finest ones are used for canning, tomatoes which are picked from the vines only after they have thoroughly ripened. They are first heated for a short time in boiling water to loosen the skins, so that these may be easily removed. At the same time many of the bacteria which cause decay are killed.

After the skins are removed, the tomatoes are placed in cans. In common practice the cans are closed except for a small opening for the escape of steam, and then placed in a cooker. Cooking is continued in the cans at a temperature

American Can Company

These women are inspecting vine-ripened tomatoes which are about to be canned

high enough to kill all the bacteria that may have lived through the first heating. The cans are then removed from the cooker, and the tiny holes are closed. Now free from bacteria and tightly sealed, the cans are ready for market. Such canned fruits and vegetables keep indefinitely. One of the steps in their preparation is shown above.

There is need for government control in the canning industry, no less than in the meat industry. Chemicals may be used in canning to prevent the growth of bacteria. Unwholesome or even dangerous food products which have been treated with these chemicals may have the appearance of wholesome food. The use of preservatives in canned foods is therefore prohibited except under carefully controlled conditions.

If you consider the importance of the health regulations we have discussed above, you will see that as consumers, or users, we must look to our government for protection against practices that might harm our health. We must be assured by responsible government agents that the food we buy is fit to eat.

Exercise. Look over the foods in your kitchen at home and see if you can discover some of the ways in which they have been protected against dirt and bacteria before they reached you.

THE PROBLEMS OF PROTECTING OUR MILK AND WATER SUPPLIES

What Milk Is. There is no food more beneficial than pure milk, and none more dangerous when improperly prepared for the market. Let us in this section follow with care the steps in preparing cow's milk for human use. First of all, what is milk? It is mostly water; but it also contains fats, proteins, carbohydrates, mineral salts, and vitamins. The proportions of the substances in a typical sample of cow's milk are as follows:

	Per Cent
Water	87.1
Milk sugar	5.1
Fat	3.9
Protein	3.2
Mineral salts and vitamins	0.7
	100.0

Effects of Bacteria on Milk. You doubtless know something about the problem of keeping milk fresh. Milk is good food for bacteria and other small plants as well as for human beings. When left exposed in warm weather, milk is soon changed by bacteria, as the following experiment will show.

Exercise. Test some fresh milk with blue litmus paper, which turns red in the presence of an acid. Does the paper change color? Leave the milk in a warm place for forty-eight hours, and test it again with blue litmus paper. Does the paper change color? Have the taste and the appearance of the milk changed?

What is the origin of the acid in sour milk, and why does sour milk curdle? The answer is that bacteria get into milk and feed on the milk sugar, changing it to lactic acid. This acid, like all other acids, produces a sour taste and turns blue litmus paper red. As the acid forms, it causes the milk to curdle by separating the protein from the rest of the milk. You may easily demonstrate the fact that acid causes milk to curdle.

Exercise. Put some fresh milk in a test tube. Add a drop or two of dilute hydrochloric acid and observe what happens.

The bacteria that cause milk to sour and curdle are not harmful. You probably know that cheese is made from sour milk. Bacteria or molds growing upon cheese give it flavor, different kinds giving different flavors. Cream is usually soured before it is made into butter. Similarly, there are many harmless bacteria in every glass of sweet milk that comes to the table. These harmless bacteria will multiply rapidly if the milk is warm, but much less rapidly if the milk is kept cold. If all the bacteria and other small

Cheese is made from sour milk

Galloway

plants are killed, as is the case in canned milk, the milk will keep indefinitely.

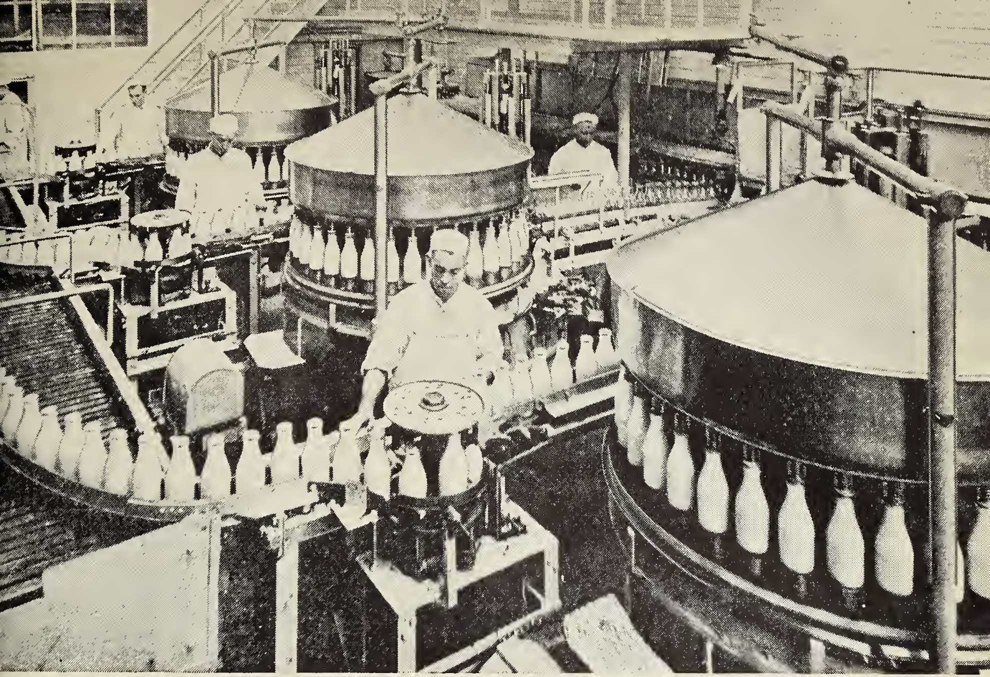
Unfortunately, bacteria that produce disease may also be present in milk. Cows may have tuberculosis, and the bacteria of tuberculosis may get into the milk. Dairy cattle are therefore examined at regular intervals by government inspectors, as shown on page 97. If the cows are found to have tuberculosis, they must be destroyed.

The greatest danger to milk are the bacteria of disease that may get into it from the hands of people who themselves are suffering from disease. In the past, many cases of typhoid fever, diphtheria, and other serious illnesses have been traced to milk. Cows do not have typhoid fever or diphtheria, so the bacteria that produce these diseases are never present in the milk as it comes from the cow. They get there from unclean handling.

The Modern Dairy. In a well-run dairy every precaution is taken to bottle milk so that it will remain sweet for a long time, and so that bacteria of disease cannot get into it. Suppose we visit a dairy farm and see how this is done.

Notice that the modern dairy barn, as shown on page 61, is very clean. The cows are regularly washed before milking. The milking itself is done by machines, and the parts of the machines are sterilized before the milking is begun. The workmen are dressed in white, and a fresh suit is used for every milking. Before handling the machinery the workmen very carefully wash their hands. The barn seems almost as clean as a hospital. "Why so much care?" you may ask. The answer is simple enough. It is only by extreme cleanliness that bacteria in milk can be held to a healthfully low number.

In spite of all the care that may be taken, there are



National Dairy Products Corporation

leanliness and efficiency are the watchwords in this modern milk-bottling plant

some bacteria in all milk. While the milk is warm, the bacteria develop rapidly; unless great care is taken, every bacterium that gets in at the time of milking will have produced several hundred offspring within a few hours. If the milk is kept warm, it will not be many hours before bacteria cause it to sour.

The temperature of the milk as it comes from the cow is the same as that of the cow's body, which is about the same as the temperature of your body. As soon as it is taken from the cow the milk is cooled, and as soon as possible it is started on its way in refrigeration tanks to the pasteurizing plant. This is usually located in the city, and milk from several farms may come to it.

The Process of Pasteurization. What is pasteurization and why is it necessary after so much care has already been taken? It is simply an added measure of precaution to keep bacteria under control. The process of pasteurization is merely the heating of milk to a temperature which is high enough to kill any disease-producing bacteria which may be present, but not high enough to injure the food value of the milk. In common practice milk is heated to a temperature of 145° F., and held at this temperature for thirty minutes.

Exercise. Get some fresh "raw" milk and pasteurize a small part of it. How could you find out what changes took place?

Though precautions have been taken to keep the germs of tuberculosis, typhoid fever, diphtheria, and other diseases from the milk, there is always danger when milk is handled by many people that some germs will get in. If they do, they are killed by pasteurization. Some of the bacteria which cause milk to sour may also be killed. A count of 1,000,000 bacteria per cubic centimeter of milk may be reduced by pasteurization to 10,000 per cubic centimeter. After the milk is pasteurized it is poured by machinery into sterilized bottles, and the bottles are capped. You may gain some idea of the care taken to guarantee a pure milk supply by studying the picture on page 475.

Grades of Milk. The number of bacteria in milk forms the basis for classifying it for the information of the consumer. Milk with the lowest number of bacteria is known as *Grade A milk*. There are two kinds of this grade of milk: Grade A "raw" and Grade A "pasteurized." The former may be sold as "certified milk," which represents the highest standard. The cows producing such milk must be kept in sanitary barns. They must be regularly tested by a veterinary and certified free from tuberculosis. The dairy

National Dairy Council

These men spend their lives counting the bacteria in milk

workers must undergo examination and be certified free from disease.

In common practice certified raw milk must have a bacterial count not above 10,000 per cubic centimeter when delivered. Milk containing more than 10,000 bacteria per cubic centimeter but less than 200,000 may be sold as Grade A milk only after it is pasteurized. At the time of delivery, pasteurized Grade A milk must not contain more than 10,000 bacteria per cubic centimeter.

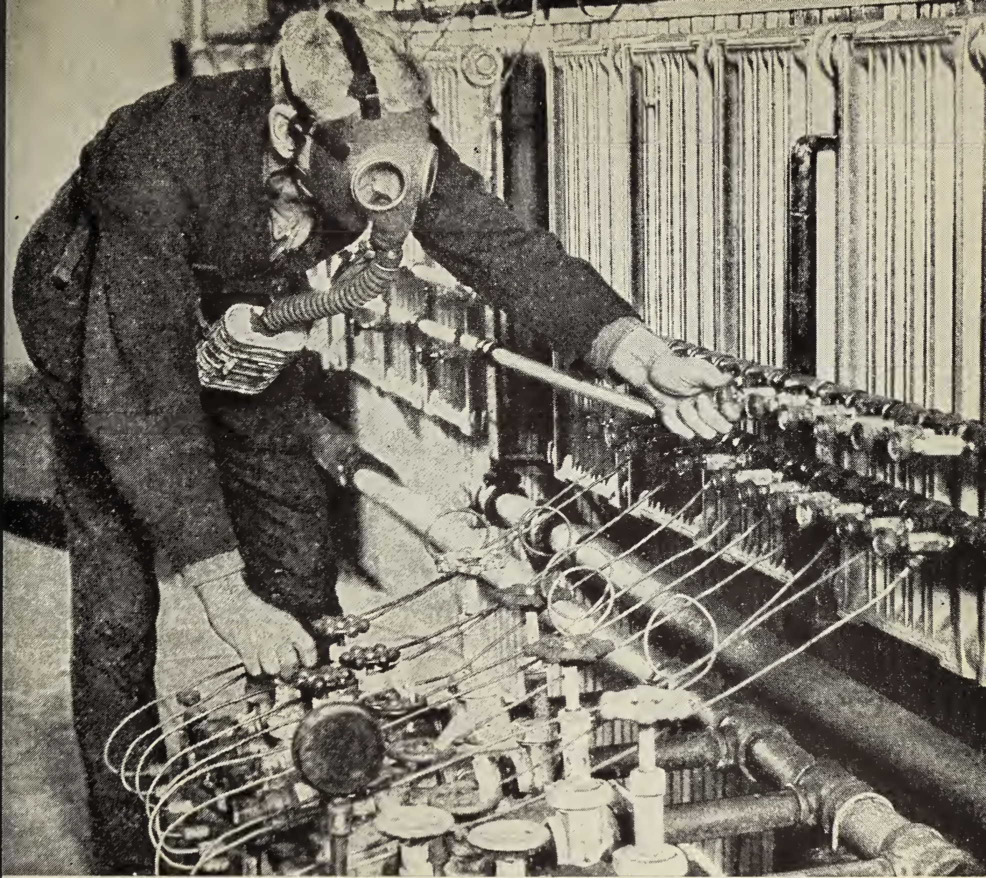
Grade B, like Grade A, milk is produced from cows that have been tested and found free from tuberculosis. In Grade B milk, however, the count of bacteria may run as high as 1,000,000 per cubic centimeter before pasteurization, but in common practice there must not be more than 50,000 per cubic centimeter at the time of delivery. Both Grade A and Grade B milk must be entirely free from bacteria that cause disease. The tendency among certain large distributors of milk is to do away with this system of grading and to market but one thoroughly high type of milk.

Exercise. Visit a dairy or a milk-bottling plant, to find out how milk is prepared for use. If a visit is not possible, perhaps you can get a motion-picture film which will give you this information.

You can see from all this that sanitary standards for milk are high. Wherever you go in our large cities you will find pasteurized milk which you may drink without any fear. This is in striking contrast with what you may safely do in many, if not most, foreign countries. It is a very good thing that our milk is so wholesome, because we are mighty milk-drinkers. Before war broke out in Europe in 1939, only Switzerland and Sweden used more milk per day per person than was used in the United States. England, France, and Germany used much less. For comparison, Switzerland used 1.83 pints per person per day. In the United States we used 1 pint. In England the quantity was only 0.44 pint.

The Problem of Getting Pure Water. Water, like milk, is subject to contamination by disease-producing germs and other substances. Like milk, the water supply in most modern communities is a public rather than a private responsibility. In your earlier work in science you have probably made a study of your local water system. We shall therefore consider only briefly here the principles on which a safe water supply may be assured.

First of all, what are the possible dangers against which we must guard? The water that flows in city mains is commonly pumped from rivers and lakes. An examination of such water would show that it contained mineral salts



Galloway

his man is regulating the amount of chlorine gas which is being added to the water supply of an American city

which were dissolved from the soil as the water flowed over the earth. It would also show that the water contained some sediment which would make it appear more or less muddy, and some unpleasant odors from decaying plants and animals. There would certainly also be some bacteria in the water, some of which might be harmful. A satisfactory water supply must have most of these impurities removed.

The sediment may be removed by a chemical process or by filtering the water through sand. It may be removed by simply allowing the tiny particles to settle in a quiet basin. If water is very muddy, such as that which is taken from the Mississippi River, it is both treated by a chemical process and filtered through sand. If there is but little sediment in the water, as is true in the case of the water taken from the Catskill Mountains for use in New York City, neither a chemical process nor sand filtering is necessary.

Most of the bacteria, as well as the sediment, will be removed if the water is filtered through sand. Bacteria which produce disease are adapted to live in the human body. Outside the body they are easily killed. In the pasteurization of milk, heat is used to kill them; in the purification of water, chlorine is often used. Chlorine is a poison for the bacteria that cause disease and that may be present in water. Scientists who have made a special study of bacteria guard the water supply by making counts of the number of bacteria in a measured sample at regular intervals. When the count runs high, more chlorine is used; when the count is low, less chlorine is used. Chlorine is sometimes used in sufficient quantity to be tasted, but never in sufficient quantity to harm those who drink the water.

Exercise. Make an examination of your local water supply and report on it in class. Be sure to include an explanation of how the problems of sediment and bacteria are solved.

THE PROBLEMS OF GETTING RID OF GARBAGE AND SEWAGE

How Garbage Decays. Great quantities of useless material collect every day in every town and city, and a large part of this material is made up of the wastes from the handling and preparation of foods. There are fruit peelings and seeds, pods of peas and beans, nutshells, waste leaves from

Jayne

The garbage heap is a nursery for disease-spreading pests

green vegetables, spoiled foods, and many other things. The waste materials in this so-called garbage are chiefly of plant or animal origin. Since this is so, almost everything in garbage is food for bacteria and other small plants. Much of it is food for rats and mice, and for flies and other insects in great variety.

You may have seen garbage dumps on the outskirts of a large city. What becomes of them? As the bacteria, molds, and other forms of life feed on it, garbage is reduced to the chemical elements of which it is composed. Carbohydrates and fats, as you probably know, are composed of carbon, hydrogen, and oxygen. Proteins contain these same elements, together with nitrogen, sulfur, and small amounts of certain other elements. The mineral salts are compounds containing calcium, phosphorus, sodium, potassium, and a few other elements.

We say that garbage decays, but when we study decay we find that it is only the change that takes place as a result of the feeding of living creatures. You know how foods are used in the cells of your own bodies. Energy is released from the foods as they combine with oxygen. The carbohydrates and fats are changed to carbon dioxide and water. Proteins are reduced to these same simple compounds and to compounds of nitrogen, sulfur, and a few other elements. The chemical changes in decay are much the same as those that take place when energy is released in the cells of the human body.

Bacteria and molds are the chief agents of decay. In the garbage heap where there is plenty of food for these creatures, they multiply to enormous numbers. In the process of decay garbage is changed into simple substances, mostly carbon dioxide and water, and a small amount of mineral compounds. When proteins decay, compounds are released as gases which cause disagreeable odors.

The Problem of Flies and Rats. The garbage heap is an extremely objectionable thing. Probably of more importance than the disagreeable odors is the fact that garbage serves both as a source of food and as a breeding place for pests. Among the pests that breed in decaying garbage, flies are the most objectionable.

You probably already know the life history of the housefly. Eggs are laid on partly decayed matter, which serves as food for the maggots that hatch from the eggs. In warm weather the interval from egg to maggot to adult fly is about twenty days. Since a single fly may lay more than a hundred eggs at one time, during warm weather there will be a swarm of young flies rising continually from a heap of decaying garbage.

You don't need to stay about a garbage heap very long to learn that it is alive with rats. These too develop at an enormously rapid rate when there is plenty of food. One female rat will produce young as often as four or five times a year, and in each litter there will be from four to ten young. At the age of about six months the young will be old enough to produce more young ones. If there were sufficient food and if none of the rats died, one pair would have produced ninety-five pairs by the end of one year, or one hundred and ninety individuals! By the end of the second year there would be almost as many rats as were supposed to have followed the Pied Piper of Hamelin.

Fortunately, rats do not really reproduce so fast as this, because their numbers are limited by the size of the food supply. The best way of limiting the food supply of rats is to do away with the garbage dumps on which they thrive.

Rats, like flies, present a definite danger to health. It is believed that the dreaded plague which swept Europe in the fourteenth century, and which you may have heard of as the Black Death, was carried by rats. The terrible bubonic plague is carried by rats today. All countries have taken strict measures to protect their people from the spread of this horrible disease. Not only are rats a menace to health, but they are also an economic problem, as you may have realized if you have ever seen the damage these animals do to corn and other grains.

The Best Method of Garbage Disposal. The problem of getting rid of garbage, then, is an important one. What can be done about it? Some communities still have dumps, such as the one shown on page 481. Other cities collect their garbage, load it on flat-bottomed boats, and dump it in the sea. This is no solution of the problem, however, because the wind and the waves may carry some of the garbage to near-by bathing beaches.

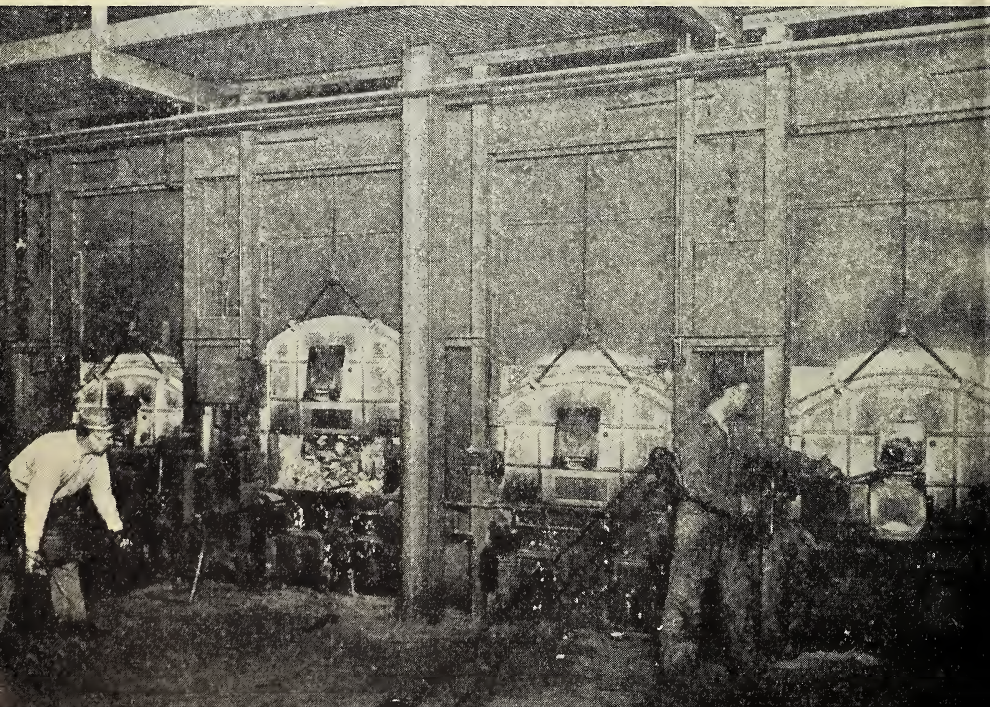
The simplest way to get rid of garbage is to burn it. In an *incinerator*, such as the one shown below, garbage is burned at a high temperature (about 900° C.). The carbon, hydrogen, oxygen, and nitrogen of which foods are composed become harmless gaseous compounds which escape into the air. There are no objectionable odors from such an incinerator because at so high a temperature even the foul-smelling gases of decay are broken down. Within a few minutes after the garbage is placed in an incinerator, there is nothing left of it but clean white ashes. These may be collected and used as fertilizer to enrich the soil of fields and gardens.

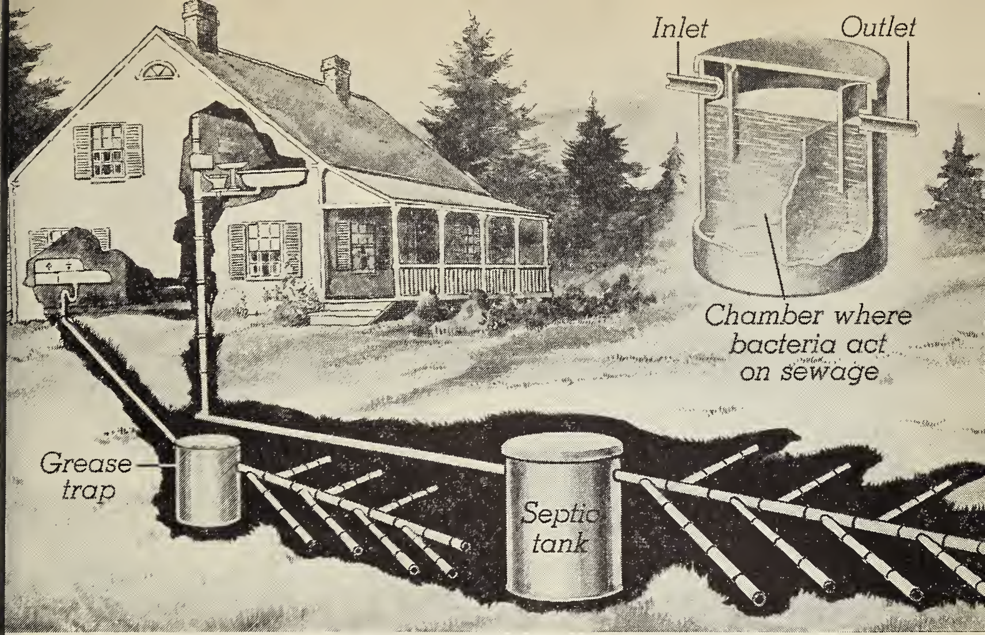
Exercise. Make a study of the method of garbage disposal in your community. Is it in all ways above criticism from the point of view of public health? If not, how might it be improved?

The Problem of Sewage Disposal. Sewage consists of the wastes from the human body and, like garbage, may carry

Burning garbage in incinerators is the most sanitary way of getting rid of it

Acme





his diagram illustrates an effective method of sewage disposal for a single residence[1]

many disease germs. As with garbage, the problem of proper sewage disposal is very important to human health. The use of simple scientific principles, however, helps to solve this problem.

Consider first the chemical composition of sewage. The waste products that make up sewage are produced from foods and are composed of the same chemical elements found in food; namely, carbon, hydrogen, oxygen, nitrogen, sulfur, phosphorus, and a few other elements. Sewage, like garbage, serves as food for bacteria and certain other small living things. These tiny plants and animals change the wastes into carbon dioxide, water, and ammonia, with very small amounts of other substances. In getting rid of sewage, conditions should be made favorable for these bacteria to live and grow, for as they grow they destroy the sewage.

Disposal of Sewage in Rivers. Some cities discharge their sewage into rivers. This practice may be permitted if there

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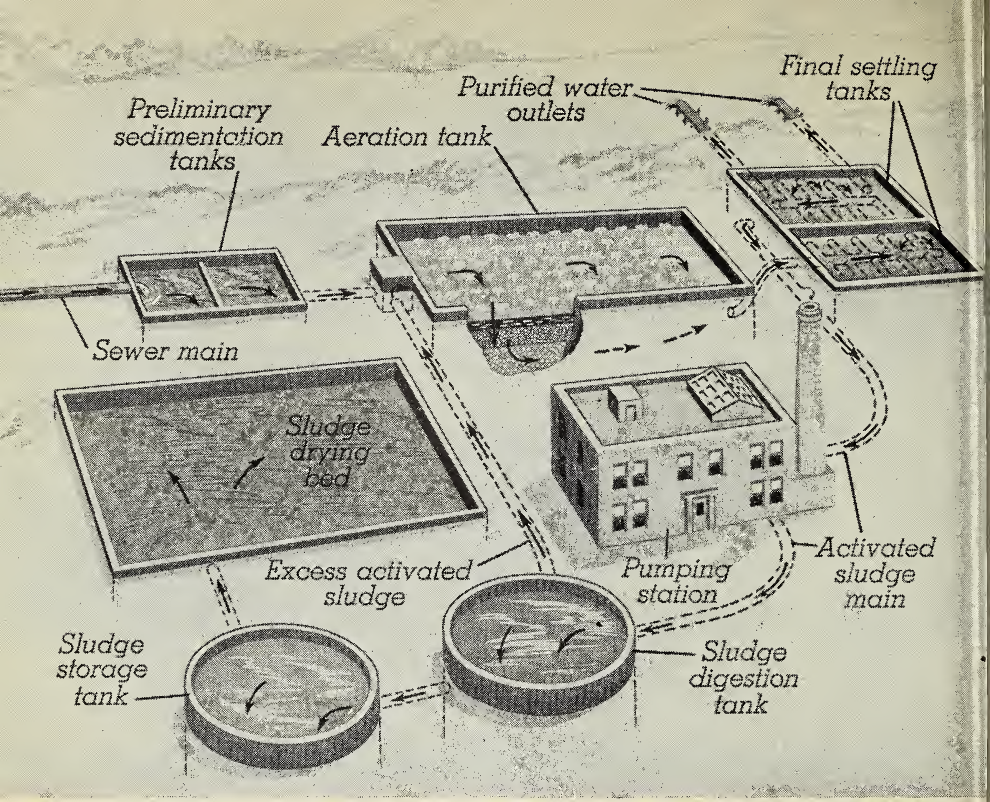
[1] From Caldwell and Curtis, *Science for Today.*



This diagram shows how a modern city disposes of sewage. What use do you suppose can be made of the sludge that develops as a by-product?

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is a large flow of water and if there are no near-by cities downstream. What happens to sewage after it flows into a stream? The bacteria normally found in the water feed upon it. When there is only a little sewage for a large amount of water, the sewage is soon completely destroyed. It is interesting to observe that cities along the Mississippi River and its tributaries dump sewage into the river, yet the water is nearly free from sewage when the great river flows into the Gulf of Mexico.

The bacteria of typhoid fever, which are likely to be present in sewage, may live for a time in a stream that carries such waste material. They feed on the sewage in the water, but when this is destroyed the typhoid bacteria die. If the water is heavily loaded with sewage, however, disease germs will live longer in it than if the water contains but little sewage. In thickly settled regions, therefore, where towns are close together, the practice of dumping sewage into a stream is objectionable and dangerous to health.

Septic Tank. There are other possible ways of getting rid of sewage. The sewage from a single residence may be effectively taken care of through a septic tank, as illustrated on page 485. This system, while it may seem complex, is simply a means of providing conditions favorable for the work of bacteria. As the sewage is held in the tank it is changed into liquids and gases. There is an overflow pipe near the top of the tank, through which the liquid flows out and seeps away in the surrounding soil.

Many large cities take care of their wastes through special plants. In their commonest form these plants are large septic tanks, as shown on the opposite page. Without ques-

his sewage-disposal plant at Cleveland, Ohio, is just one example of how the modern American city safeguards the health of its people

Public Works Administration

tion this is a far more satisfactory way of getting rid of sewage than dumping it into near-by streams. Regardless of the plan used, however, modern methods of sewage disposal must all operate on the same principle. They must make conditions favorable for the growth of those bacteria which feed upon and destroy the sewage.

Exercise. Make a study of the method of sewage disposal in your community. Is it completely satisfactory from the point of view of public health? If not, how might it be improved?

The Blessing of Public Health. In this chapter we have considered a few of the more important problems which illustrate the necessity of public-health practices. There was a time when the relationship between sanitation and health was unknown. Epidemics of bubonic plague, cholera, malaria, yellow fever, typhoid fever, and other dread diseases broke out again and again, with great loss of life. No one knew why they broke out or how to control them. Not long ago people generally believed that these diseases were the work of the devil. One can still find people who lay the blame for their ills on broken mirrors and black cats, and who seek protection in a rabbit's foot or a horseshoe.

Wiser people put their faith in science. Today the causes of many diseases are so well known and so effectively controlled that cases are extremely rare. If, for example, a case of typhoid fever were to break out in an American city, it would probably come from either milk, water, or sewage. The board of health could probably very quickly trace the case to the cause that produced it. It would probably be able to place personal responsibility on the individual whose negligence allowed the case to develop.

With such protection in mind we can pay our taxes with less grumbling. We can know that at least as far as public health is concerned we are getting our money's worth and more.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Public-health measures are necessary only because certain individuals refuse to take the proper care of their health.

2. If partly spoiled meat is frozen, it can be preserved and safely eaten at a later date.

3. Chemicals can be safely used to preserve meat because they do not work on meat that is partly spoiled.

4. Canned foods are not so healthful as fresh foods because they contain more bacteria.

5. When milk turns sour it is because disease-producing bacteria have entered it.

6. The greatest danger in using milk is that cows suffering from typhoid fever may pass on some of the germs to the person who drinks the milk.

7. Milk that is cooled as soon as it comes out of the cow is said to be pasteurized.

8. Grade A milk is better than Grade B milk because it is richer in cream.

9. "Certified" milk is just another term for "pasteurized" milk.

10. Chlorine is a poison and therefore unsafe to use in purifying drinking water.

11. Flies are the chief cause of the bad odors of garbage.

12. The best way of disposing of garbage is through the use of the septic tank.

13. The best way of disposing of sewage is to throw it into rivers.

14. Public-health measures in large cities cost more than they are worth.

Questions for Discussion

1. Do you believe that public-health measures are more important in the city or in the country?

2. What standards should you use to judge the protection which your community provides for the health of its citizens?

Things to Do

1. Make a study of your community to find out how its health is protected. What health officials are there, and what are their duties? Are there any conditions which are dangerous to community health? How may they be corrected?

2. Do you think our present laws are sufficient to protect public health? Discuss this question after you read *One Hundred Million Guinea Pigs.*

3. If you have a public-health officer in your community, ask him to speak to your class on the ways in which foods are tested for impurities.

4. One of the outstanding men in the fight for pure-food laws was Dr. Harvey W. Wiley. Find out about him and write a short account of his life and work.

UNIT FIVE

THE CONSERVATION OF WEALTH

You have now come to the final unit in this book on using our world.

You have seen how rich we are in natural resources, and how well we are using this wealth to improve the conditions of our lives.

* * *

Doubtless as you made your way through the earlier chapters you caught glimpses of certain less pleasant aspects of man's adventures on earth.

You doubtless observed that man has abused, as well as used, his natural riches.

How much at the same time has he abused himself?

* * *

Exactly how much of his natural treasure has he thrown away?

How much is gone beyond recall?

How much can be brought back with the help of modern science? In short, should we practice conservation of natural resources, and if so how can we do it?

* * *

To a very great extent the future welfare of humanity depends on what answers we give to these questions.

This unit will do its best to discover the right ones.

CHAPTER SEVENTEEN

Why Must We Practice Conservation?

THE BALANCE OF NATURE

Nature without Man. In Chapter Three we saw something of the care with which we protect our domesticated plants and animals. But what have we done to protect the wild plants and animals which make up by far the largest part of the living resources of earth? What have we done to protect the lands and waters that support them? The best way of answering these questions would be to compare a region before man came to live in it with the same region many years after man had settled there.

We cannot quite do this with our own continent of North America, because we do not know exactly what it was like before the Indians arrived there, as scientists believe, from Asia. But we can nearly do it, because when the first white men arrived from Europe they found an almost uninhabited wilderness. At that time there were probably not so many Indians in all of what is now called the United States as there are people in the city of Cleveland today.

The Indians, of course, had their cornfields. These, however, disturbed the land very little. They were no more than large gardens, usually planted in the flat, rich bottom lands of rivers. Without steel tools and work animals the Indians could not do much damage to the forests, even had they wished to. Furthermore, they needed the game, fish, nuts, roots, and wild fruits which were so abundant wherever they went. They had no wish to change the landscape so that these sources of livelihood would be harmed.

From what we know about the condition of North America before the white man arrived, we get a glimpse of what seems to be a general truth. *Unless man interferes, the surface of the earth is as completely covered with living things as possible.* We can get more light on this same general truth from certain observations in our own neighborhood today.

You have probably noticed that small, fast-growing, short-lived weeds are the first plants to move into a bare place. But if you watch such a place for several years, you will see that the weeds are only a sort of advance guard for the main army of vegetation. Slowly other kinds of longer-lived plants come in to take the place of the weeds, until a permanent meadow or a wood is established. The plants that finally make up this meadow or wood are those which can best adjust themselves to the soil and to one another.

As new kinds of plant life move in and change, so do new kinds of animal life. You do not find squirrels, deer, and woodpeckers in a weed patch. Instead you find beetles, sparrows, and rabbits. But when the weed patch becomes overgrown with shrubs, and the shrubs by trees, then the animals of the forest enter and make themselves at home.

While this is going on, the ground beneath is changing too. Dead leaves and sticks, the droppings of animals, and occasionally their dead bodies fall upon the ground and decay there, adding new substances to it and darkening its color. Roots, worms, and larger animals burrow through the ground, opening up its spaces and enriching it. The result of all this is that new and more fertile soil is formed which is able to support more and more plant and animal life. *If nature is undisturbed by man, then, the earth be-*

comes a better place to live in by being lived upon. It is something like a well-designed and well-built home or a good violin—it improves with use.

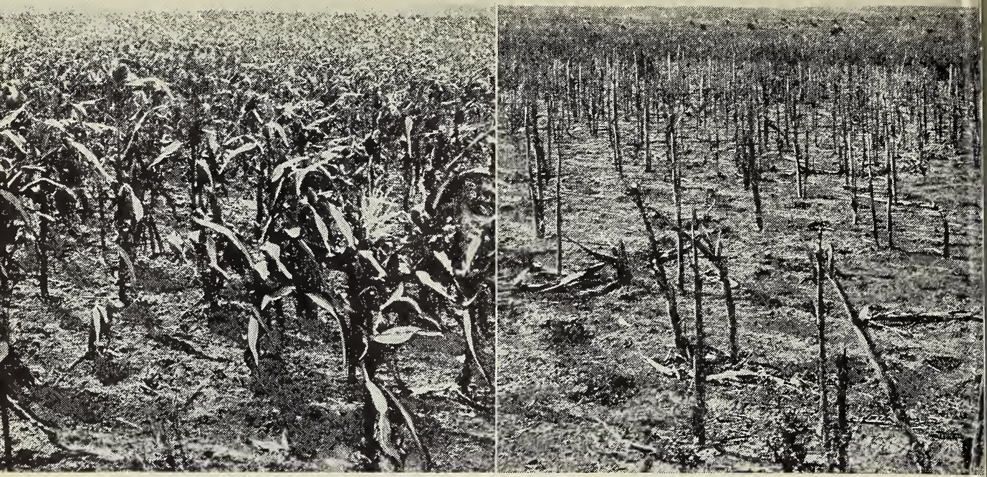
The Relationships of Living Creatures. We must understand, however, that this does not mean that the earth becomes better for any one particular kind of plant or animal because of such changes. It becomes better suited to support a variety of living things in communities in which the members are adjusted to one another and depend on one another in many ways.

Let us briefly consider the relation of the squirrel to other living things. He eats nuts, but he also buries them and thus makes it possible for them to grow into trees. He nests in hollow trees which are decaying because of the activity of molds and similar plants (the fungi). These plants may have gained entrance to the tree through beetle holes or through holes opened by woodpeckers. The body of the squirrel may harbor insects—in fact, it generally does. Other insects and fungi feed on the leavings of the squirrel's feasts, and still other creatures feed on the squirrel. There is a similar story for every wild plant and animal in the world. Each one is related in one way or another to its neighbors.

Exercise. Make a list of several plants and animals in a woodland or meadow. Find out upon what each animal feeds, how the plants form seed, and how their seeds are spread and planted. Can you discover any animal or plant that lives entirely by itself?

Science has a term for the relationship which binds different kinds of living things to one another, to the soil, and to the climate in which they live. This term is "the balance

The earth teems with living creatures where man has not upset the balance of nature



U. S. D. A., Bureau of Entomology and Plant Quarantine

The cornfield on the left was productive because the balance of nature was preserved
The cornfield on the right was destroyed by insects when the balance was upse

of nature." It suggests that relationships within a community of living plants and animals are very delicately adjusted, or balanced, and this is approximately true.

Suppose, for example, that more squirrels got into a woodland than the woodland could support. We all know what would happen. Without enough food to go round, the squirrels would fight with one another until many were injured or killed. Hunger would drive them to eat more than the usual amount of tree buds (of which they are very fond) in the early spring, and thus to reduce the autumn crop of nuts. It is entirely likely that after a time there would actually be fewer squirrels than the woodland could support. Gradually, however, the situation would correct itself and become as it was before the natural balance was upset.

MAN AND THE BALANCE OF NATURE

Man's Place in Nature. Whenever a new kind of plant or animal establishes itself in any place on earth, it changes the balance which existed before it came. We have seen some examples of this in Unit One. Even such a tiny animal as the Japanese beetle, which is so destructive to gardens and lawns, can create a great disturbance. It should therefore be easy to understand that when man establishes himself in any place, he too upsets the balance of nature.

Just what is man's place in nature? To begin with, man is a newcomer. Most of the plants and animals about us (excepting the domesticated varieties which have come into existence by artificial selection) were here long before we were. Before our coming these plants and animals had established their own balance. They had their own system of natural communities which got on very well indeed.

What has man done to this harmony in the living world? An individual man may seem quite powerless to change the great world that surrounds him. But working in cooperation with his fellows, and using the tools and other instruments which he has invented with the help of his powerful brain, man as a species has become the strongest of all living creatures. The mighty herds of bison and the equally mighty forests of our continent, to mention but two examples, have given way before him. Even the tiny disease-producing bacteria, whose strength lies in the fact that they are invisible to the naked eye and can increase so rapidly in number, are yielding to the superior power of mankind.

How Man Disturbs the Balance of Nature. Let us see exactly what happens when man moves into a region where no human beings have lived before. Let us suppose that a family moves into the "backwoods," as the great-grandfathers of many of us once did. The family ox or horse goes along, perhaps a cow, a few sheep, pigs and chickens, and of course a dog. The ax, rifle, hoe, spade, and other

Man changes the face of nature

tools and household utensils are important parts of the baggage, and so are the seeds which will form the basis of a garden when the proper place is found.

We often hear the expression "carving out a home in the wilderness," which means that trees are felled to build cabins and to clear the ground for crop and pasture lands. This kind of destruction of trees is absolutely necessary in backwoods pioneering. Generally, more trees must be cut than can be used, and so fire is employed to destroy the unwanted surplus.

Beyond the edge of the clearing the forest furnishes an abundance of game, nuts, fruit, and sap for making sirup. So far as water is concerned, there is not much of a problem. With no other people near by, water from any stream can be drunk with safety, and there is apt to be plenty of fish to add variety to the diet. On the other hand, things like flour, sugar, coffee, salt, and tobacco are scarce and hard to get.

Presently other families come to join the first, and perhaps a little settlement grows. More trees must be removed, more ground plowed, more game killed, and more wolves and other destructive animals disposed of. Fire may escape into the forest and in a day's time destroy more trees and game than ordinary use would destroy in many years. Roads are built, canals and drainage ditches dug, and perhaps the surplus lumber is shipped out. Many of the wild animals which are not particularly good for food may be hunted for their skins. Some of the greatest early American fortunes were built on the furs and skins of wild animals.

There is no need to carry the story further. It is obvious that in the end the face of nature is changed. Man and his works replace the forest and its inhabitants. Sometimes the game is deliberately slaughtered until little is left. More often it disappears because men destroy the places where it breeds and the foods upon which it depends.

Exercise. Make a study of the region around your home. Try to imagine what it looked like before human beings came to live there. Make a list of all the ways in which you believe the landscape has changed as a result of human activities.

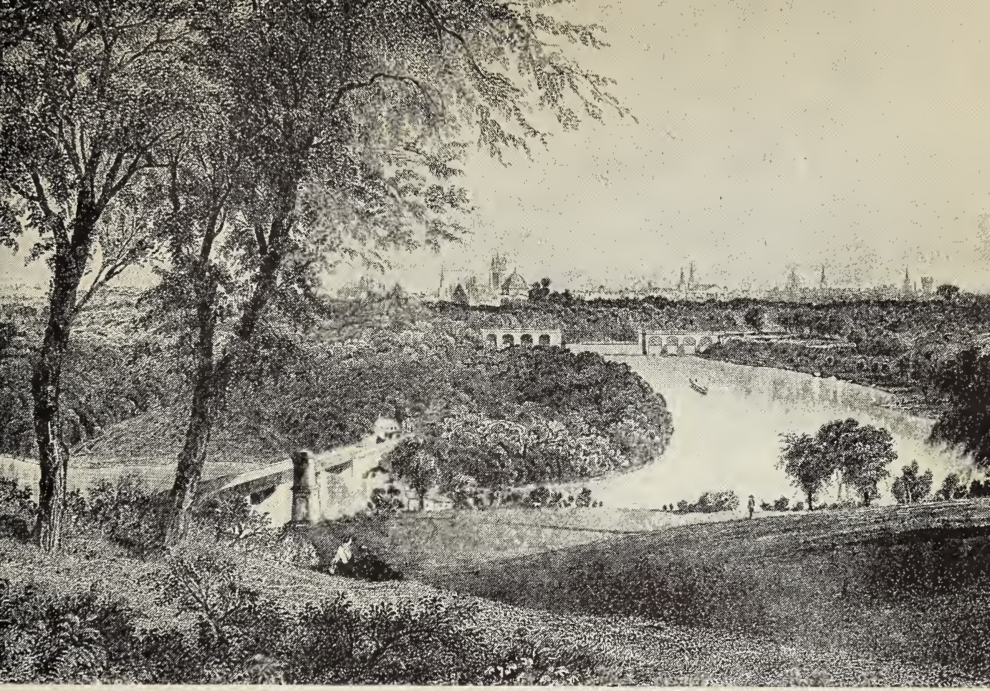
What Happens When Man Destroys the Balance of Nature. If cities, homes, and farms cannot be established without changing nature, why worry about it? Before we can answer this question we must study some of the things that happen to man as a result of what he has made happen to the world around him.

One thing that happens to man is that foods which are abundant in wild nature become very expensive and hard to get. This is true, for example, of delicious wild game and fresh-water fish, of the hickory nut and sugar made from the sap of the maple tree. Beaver fur, from which hats used to be made for any man who could afford to wear a hat, has become very scarce. "Buffalo" robes, which used to sell for five dollars each, are now not to be had at any price.

For many of these things we have cheaper substitutes which do very well indeed. A much more serious problem is the scarcity of wood, which used to be very cheap and abundant but is now quite expensive. True, we now make many things out of mineral materials which once were made of wood—buckets, ships, houses, and even furniture. But there are many purposes for which no better substance than wood can be found. One of the most important uses for wood is in making paper and artificial fiber. No other material is nearly so good as wood for this particular purpose.

Exercise. How many uses of wood can you name for which some other material would not do just as well?

Under natural conditions many parts of the earth do not have a forest covering. This is true of the American prairies, the steppes of Europe, and many other places. Such regions, unless the plant life is extremely sparse, are capable of supporting great herds of grazing animals. Under natural conditions these herds are kept in check both by the amount of the food supply and by flesh-eating animals.

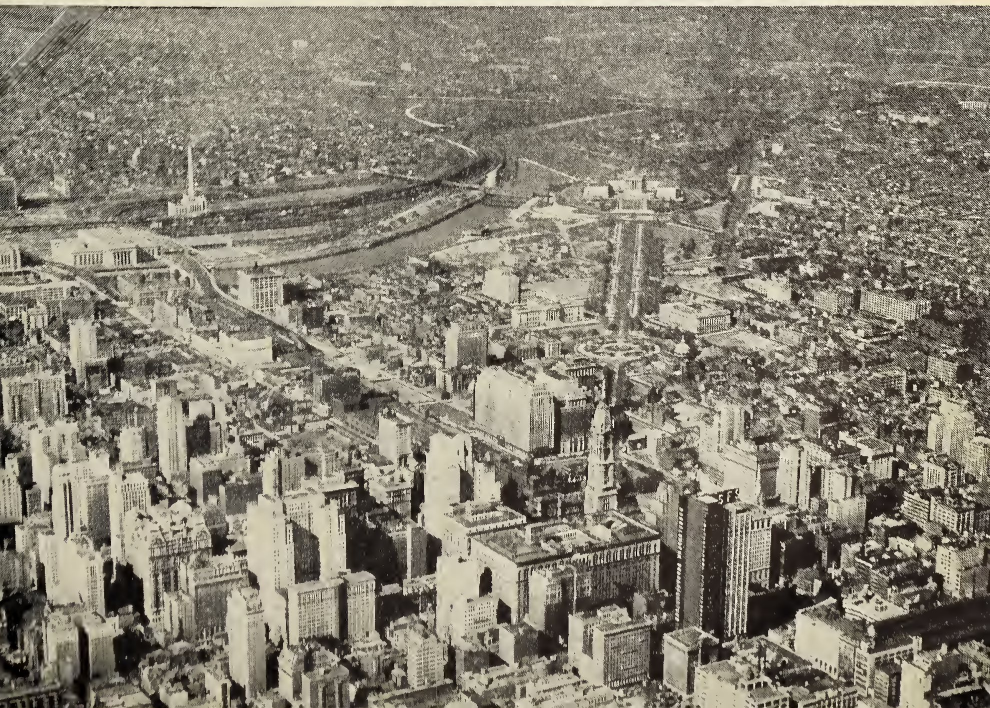


T. F. Healy Collection

In 1873 Philadelphia was a combination of nature and man

Today Philadelphia is chiefly man

Fairchild Aerial Surveys, Inc.



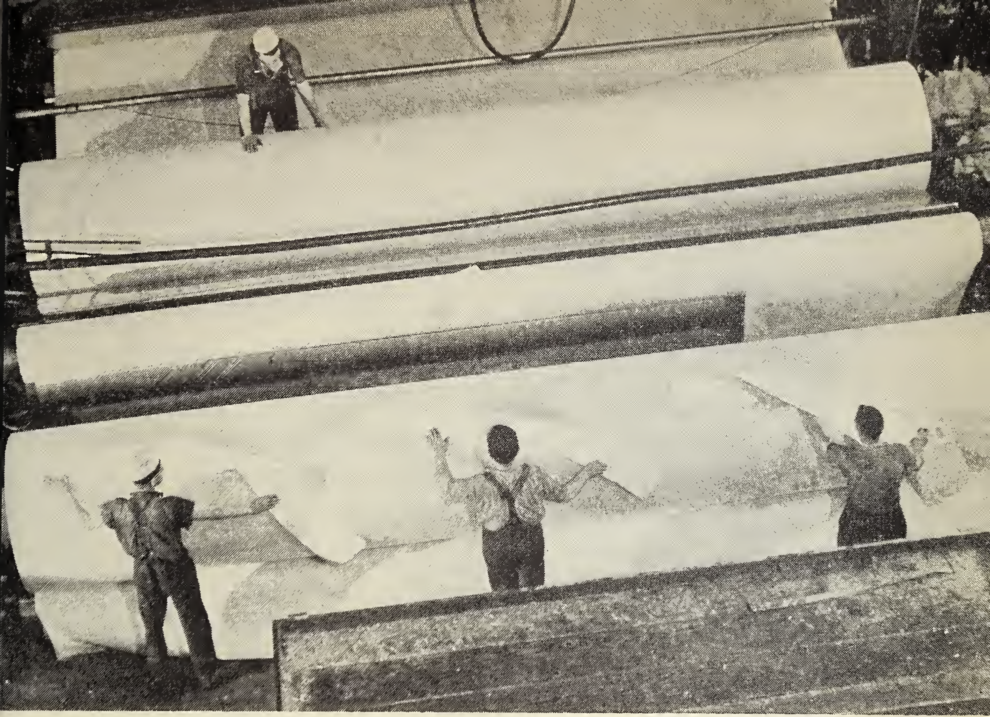
Under civilization, however, man very often crowds too many of his domesticated animals into such places. Presently the grass is eaten so close that in dry years it does not afford sufficient food. Furthermore, man plows up much of this treeless country to grow crops, which reduces the amount of pasture still more.

Unhappily, the trouble often caused when man moves into the landscape does not stop with the destruction of the forests and the grasslands. Both forest and grassland are the natural guardians of soil. When the wild vegetation is removed from the ground, much skill is required to keep the soil from being removed by wind and water faster than it is made by the crumbling of rock. The dread process of soil removal (known as erosion) has already destroyed perhaps one third of the original rich topsoil of the United States and has made it much more difficult, uncertain, and costly to provide enough food for our people.

It is true that there are some parts of the world where soil is not easily lost. But every continent on which man has settled has suffered from this wasting disease. Regions such as northern Africa and China have suffered so severely that agriculture has almost become impossible.

The Problem of Water. Not only man himself but also his crops and his domesticated animals depend for life upon water. You can see this for yourself if you look at the maps on page 507. By comparing these maps you can see that most people of North America live in places where water is abundant. Much of Nevada, the driest state in the United States, has less than one person to each square mile.

Water, to be useful, must get into the ground. Where the ground is covered with trees or grass and the rich top-



Margaret Bourke-White

Many trees had to be destroyed to make these great rolls of paper

soil is in place, a large part of the rain water soaks into the ground and is stored there as in a great reservoir. From this reservoir came the many springs and streams of clear water which once were abundant in this country. The underground water is also the source of the water in wells.

Today most of the springs are dried up, and we must dig deeper than ever to get wells. Water is no longer being stored in the ground as it was before the days of civilization. It runs rapidly off the bare fields and roads and out through the drainage ditches which we have made. Thus we see the importance of that precious substance, water. We see that the balance of nature makes efficient use of water, and that the problem of maintaining a proper water supply is one that man creates by destroying that balance.

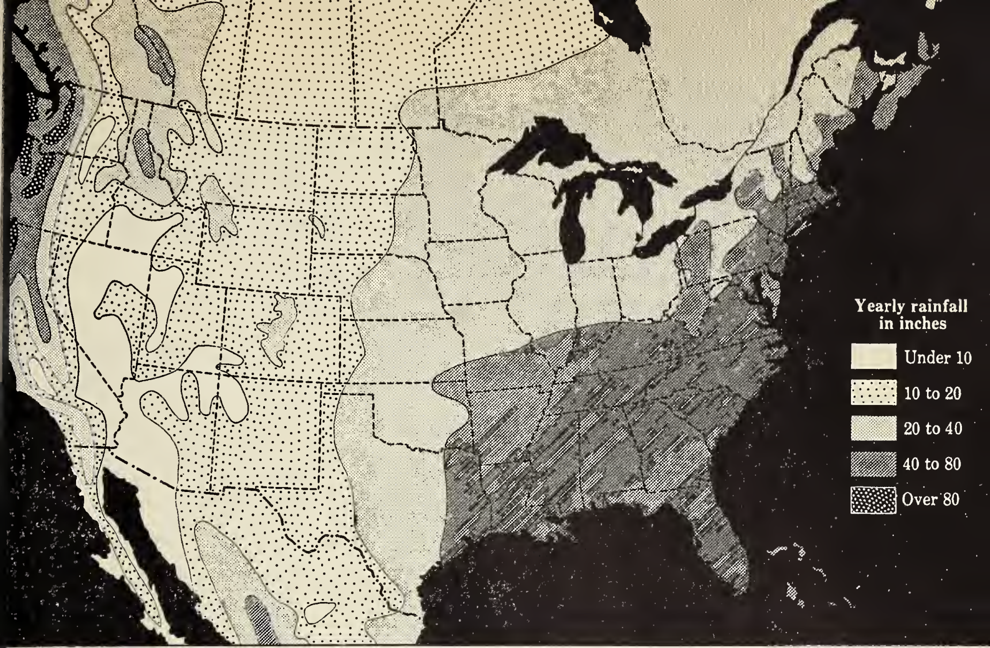
Exercise. See if you can find any old records of the depth at which water once stood in the wells of your vicinity. Is the underground water nearer to or farther from the surface now than it was several years ago? If there is any noticeable difference, how can you explain it?

We must not forget that it is the fast-moving wasted water which steals the soil from our fields and gives it to the streams and lakes. The streams and lakes in their turn are made unfit for the abundant fish and other wild life which they once supported. Worst of all, the water rushing so rapidly into the rivers after every rain increases the danger and severity of floods, while the drying of springs and creeks at the heads of rivers turns once beautiful waterways into mere trickles during the dry season.

The Problem of Climate. It is often said that our climate is changing. That statement is made, however, by people who depend on their childhood memories of cold winters or wet summers. If we examine the records of the Weather Bureau, we find that it is not really true, so far as the brief history of the United States is concerned. Only over much longer periods of time does climate truly change.

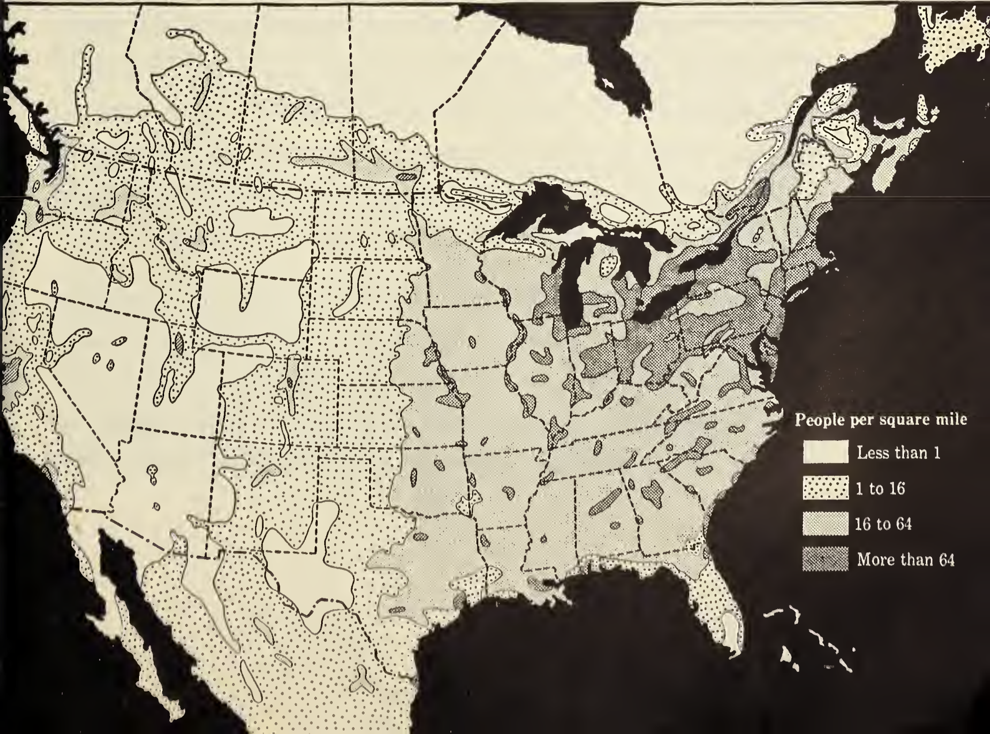
To be sure, climate is not the same in any given place from year to year. Like the stock market, it has its ups and downs. There seems to be a general tendency for groups of dry years and groups of wet years to occur together. Yet this behavior is so irregular that it cannot be used safely to predict climatic conditions very far in advance, at least with our present knowledge.

As long as either trees or grasses cover the ground, much of the moisture that falls from the sky is able to soak into the ground. Many times more moisture runs off bare ground than off covered ground. In one way, therefore,



This map shows how rainfall is distributed in North America

is map shows how population is distributed in North America.
fter comparing the patterns of this map and the map above, what do you conclude?



people are right who say that the climate is drier since the ground has been laid bare. There may be just as much rainfall on the average as before, but it does less good because more of it is lost by runoff.

In the balance of nature the plants and animals of any given region have become adjusted to these ups and downs of climate. Not all years are equally favorable to all kinds of living things. There are so many kinds of living things, however, that no year is wholly unfavorable to all of them. In the prairie, for example, the wetter years favor the taller kinds of grass. During the drier years these are not so conspicuous; instead, the shorter kinds which grow with them are more likely to thrive.

When man clears away the native growth, he puts in its place a few kinds, and in many cases only one kind, of crop. Some years this crop will do wonderfully well, but in others it may fail completely. This was true of much of the wheat in the western United States during the severe drought of the 1930's. In other words, man is likely to grow too few kinds of plants. He is likely to forget that bad years must sooner or later follow good years. So it is that he destroys too much of the natural vegetation which would yield him something, no matter what the weather conditions happened to be in any particular year.

Exercise. Make a survey of the crops grown in your vicinity. Do you believe that the farmers would be more prosperous if they raised a greater variety of crops?

A New Balance of Nature. As long as man is dependent upon plants and animals for many important needs, he must see to it that the earth produces these things. Yet we have seen how, by his destruction of the balance of nature, he frequently causes the earth to produce less than

Bureau of Reclamation

he problem of flood control is only one of the many problems which have grown with the growth of civilization

it did before. We have said nothing of the loss of beauty, variety, and interest in the landscape, but this too is important to him. His cities have been built at the cost of abandoned farms, burned-over woodlands, eroded lands, polluted streams, and diminished water supply.

If man were suddenly to disappear, nature would strike a new balance. Slowly the earth would be covered again by thriving communities of plants and animals. Soil would be rebuilt, water conserved and accumulated. But man is here, and he wants to remain. He cannot even go back to the simple life of his primitive fathers before the days of metal tools and agriculture and fit into the picture of the earth without attempting to control it.

So it looks very much as if modern man must try to work out a new balance of nature, with himself as a part of it. This means that he will have to design and plan the surface of the earth in such a way that he can keep the good new things which he has invented and at the same time have the benefits of the old balance of nature which he has so badly upset. But how can this be done? The following chapters will try to answer that question.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. There is no way of knowing what man does to any particular part of the earth because there is no way of knowing what the region was like before man came to live there.

2. The North American Indian had destroyed most of the native nut trees before the white man arrived.

3. Were it not for the interference of man, all parts of the land areas of the globe would be covered with forests.

4. Once the trees are cut off a piece of land, weeds take possession and never allow the trees to return.

5. The wolf and other flesh-eating animals are completely independent of all other living things.

6. Once the balance of nature has been disturbed it can never be restored.

7. Because of his great intelligence man never disturbs the balance of nature.

8. Because of our modern game laws, wild animals are more abundant now than they were one hundred years ago.

9. The grasslands today support more grazing animals than they did in the past because man has introduced great numbers and varieties of domesticated cattle and sheep.

10. The soil of America is deeper and richer today than

it was before civilization came to this continent, because rocks have had more time to crumble and produce new soil.

11. Because of dams and similar public works, there is more underground water available today than ever before.

12. It is definitely known that the climate of North America is getting more severe each year.

Questions for Discussion

1. Do you believe that there is any such thing as a complete balance in nature?

2. Are there any natural resources being wasted in your neighborhood? If so, what could be done to save them?

Things to Do

1. If you do not already have a balanced aquarium or terrarium in your classroom, ask your teacher to help you set one up. Consider especially the things you have to guard against in order to maintain a natural balance.

2. Take a census of the wild animals in your neighborhood that people consider harmful, paying special attention to snakes and hawks. After carefully considering the habits of each of the animals on your list, mark those that you believe do more harm than good. Mark those that pay for the harm they do by helping to preserve the balance of nature. Against how many animals on your list do you believe we are really justified in waging war?

3. Write to your congressman for a list of publications that deal with the conservation measures which are now being practiced in your region. Obtain some of these publications and, after studying them, decide if the measures are sufficient to meet your local conservation problems.

4. Read Katherine Glover's *America Begins Again.*

CHAPTER EIGHTEEN

How Can We Conserve Our Plant and Animal Wealth?

THE PROBLEM OF SAVING OUR FORESTS

The Difficulty of Both Using and Preserving Our Forests. In the last chapter we saw that when the backwoodsman moves into a forested region the trees very soon move out. In his conquest of the wilderness the white man has cleared many millions of acres of wooded land. The need of clearings for farm lands and of lumber for buildings was and still is a real one. The need of forests, however, is also a real one, as we are unhappily learning now that our forests are fading away.

How can these two opposing needs be satisfied? How can we have our cake of forested lands and at the same time eat it up to provide clearings and lumber? Before we can answer these questions we must know more about the general relationship of trees and men.

How the Red Man Used the Forests. In the last chapter we saw that before white men came to America, red men were using the land without abusing it. Let us look a little more closely at the red man's relationship with the forests. Let us see if we can discover why this relationship was different from that of the white man and the forest.

When Europeans first came to America, they found it a land of mighty forests and grasslands and of many streams and lakes. Countless small animals—skunks, foxes, raccoons, minks, opossums, squirrels, and rabbits—

The red man used the forests without abusing them

fed upon the plant life or upon still smaller animals that abounded in the sheltering forest. In the wooded stretches of the East roamed deer, moose, and elk, and over the grasslands farther west, the thundering herds of bison.

Through the forests the Indian hunters moved with their bows and arrows, anxious to get food and furs for themselves and their families. Doubtless they enjoyed the hunt, because it is natural for men to be pleased with their ability to outwit the wild creatures of the woods. But the Indians killed only what they needed, and neither they nor their needs were numerous.

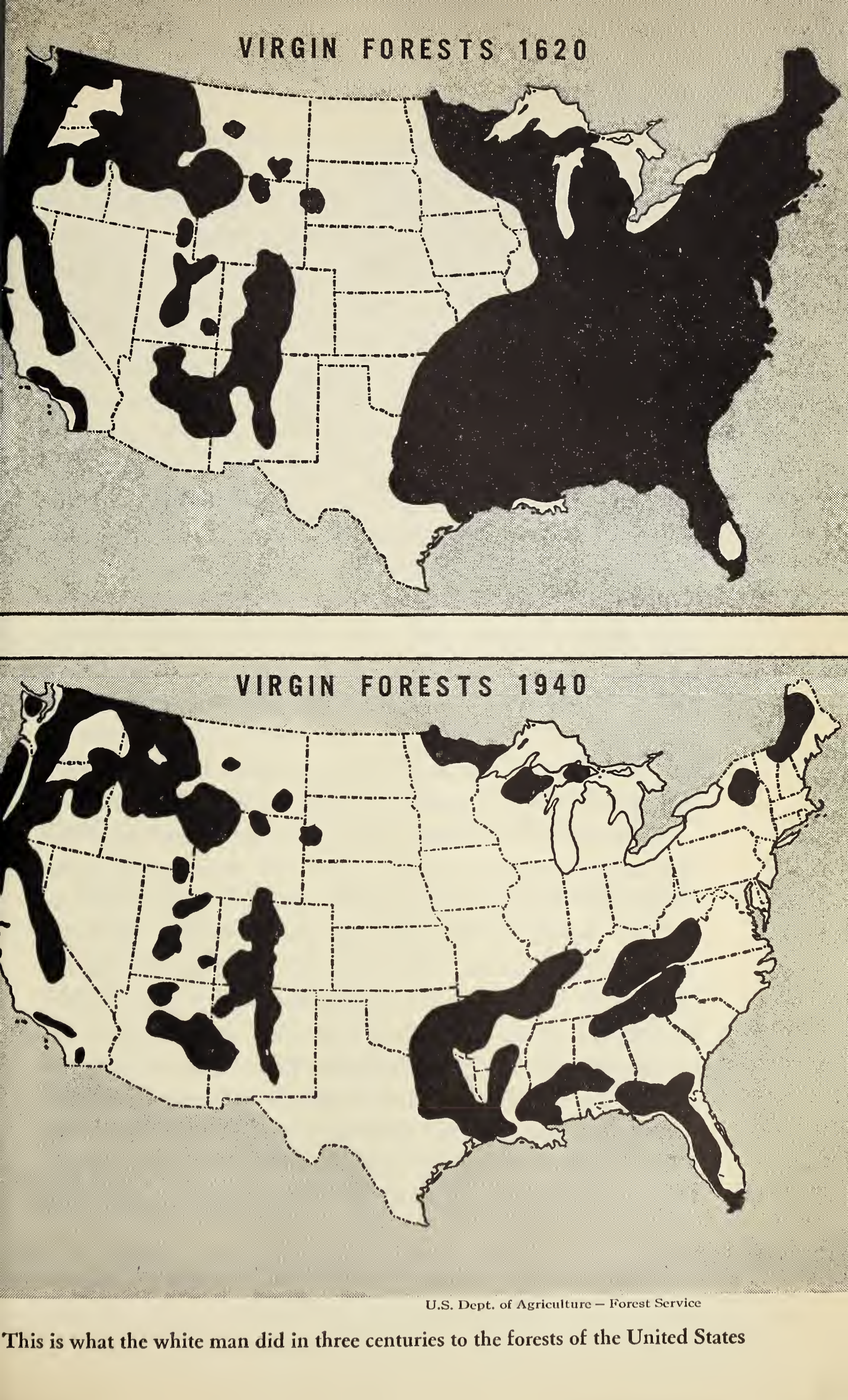
The same thing was true regarding the trees. The Indians felled a few trees for fuel and for bark and wood to make canoes and dugouts. They used branches of trees as framework for their wigwams, and slabs of wood for their "long houses." But their demands upon the forests were never great. The living trees were worth enormously more to the average Indian than all the lumber that could be made from them. The forest gave them food and protection; they loved it and were part of it.

How the White Man Uses the Forests. Why was the white man's attitude toward the forest so different from the red man's? In the first place, the pioneers feared the dangers that lurked there—the wolves and foxes that stole their domesticated animals, the hostile Indians who moved as silently and easily as shadows among the trees. It is not surprising that the pioneer desired to get rid of the trees near his home.

Then, too, clearings for houses, barns, fields, gardens, pastures, streets, and public buildings were soon needed. Little villages soon came to places that only a short time before were part of the virgin forest. We now realize that the pioneers were needlessly reckless in their destruction of trees, but the pioneers did not realize it. The vast wilderness from their point of view was filled with trees, a seemingly endless supply. Who would think of saving them or even of being careful in their use?

As the growing population of America spread westward there still seemed to be an inexhaustible abundance of trees. The map at the top of the opposite page shows the extent of the forests of the United States before the coming of the white man. Notice the unbroken stretch of forests in the East, reaching from Maine to Florida and from the Atlantic to the Mississippi. Notice the great areas of forested lands that lay to the west of the Middle Western prairies.

Our Vanishing Forests. Even though the population of the United States doubled and doubled again and again—from three million at the time of the Revolution to over one



VIRGIN FORESTS 1620

VIRGIN FORESTS 1940

U.S. Dept. of Agriculture – Forest Service

This is what the white man did in three centuries to the forests of the United States hundred and thirty million in 1940—there seemed to be timber enough for every need. But let us look at some figures. In the beginning we had about 800,000,000 acres of forested land. Today we have less than 500,000,000 acres. This means that we have a little more than half as much forested land today as we had three hundred years ago, but more than forty times as many people! The map at the bottom of page 515 will help you to realize what has happened to one of our most valuable possessions in this comparatively short space of time.

The problems of forest conservation, like the problems of saving our other natural resources, have occupied an increasingly important position in the thoughts of the American people. It is clear today that forests are no less likely to be exhausted than are coal, iron, and petroleum. At the same time it is clear that trees differ from these mineral resources in one important respect: they may be replaced. And today the wise owner, whether government or private individual, is replacing them. For every tree cut down he sees that another is planted, a policy which has been wisely and rather widely followed in Europe for generations.

To be sure, we cannot bring back the forests to areas that are given over to cities, towns, and fields. But in the United States some eighty million acres of land once covered by forests lie idle today, producing neither trees nor other valuable crops. These regions could and should be reforested. The brush that has grown up on them should be thinned out so that young trees may start to grow. In certain places more valuable kinds of trees could be planted to take the place of the less valuable varieties that have sprung up after the original trees were cut or burned down.

As a matter of fact, this task has already been begun by the government, as the picture on the opposite page will

Civilian Conservation Corps

These C.C.C. boys are busy with the important work of reforestation

show. In a few sections of the country so-called *submarginal lands*, which are not fertile enough to produce good cultivated crops, are being bought up by the government and replanted to trees. Such lands have supported forests in the past and will do so again in the future.

The Problem of Forest Fires. Even in sections of the country where forests still stand, there are problems of forest protection. Our yearly loss from forest fires has been estimated at around $500,000,000, or about one third the value of all our crude forest products. In counting the cost of forest fires we must consider not only the timber that is ready to cut but also the timber that the saplings would have produced if they had been allowed to grow to maturity. And we must not forget that forest fires destroy animals and people as well as trees.

Control of fires is one of the most important parts of forest conservation. Ignorance and carelessness are responsible for most forest fires; and the more people who live near or pass through our forests, the greater is the expected loss from fire. *The most important part of forest-fire control is to teach people to be careful with fire in the woods.*

After a fire starts, control depends as much on a scientific understanding of fire as on the number of men who can be gathered to fight any particular fire. Three things make fire possible. First, of course, there must be fuel. Second, there must be oxygen. Third, there must be a kindling temperature: that is, a temperature sufficiently high to start a fire. Control of fires must be sought through control of these three conditions.

In some way a spark falls among the leaves in the underbrush of the forest floor. Both leaves and underbrush are dry. They have low kindling temperatures (which means that they start burning easily), and very soon a flame begins moving through the brush. It mounts to the branches of some of the smaller trees. If these happen to be evergreens, the fire spreads more rapidly than in hardwood trees, because of the low kindling temperatures of the tar and pitch which evergreen trees contain. A strong wind supplies the fire with oxygen and carries the fire up to the leaves of the taller trees. When this happens, nothing can prevent it from raging through the forest.

The fire continues, let us say, until it reaches a wide state road. Here it stops because the flames cannot cross a broad area that offers them no fuel. But in another direction in which the flames can spread there are farm buildings in a clearing. Men work hurriedly to plow a ditch across the open fields and around the buildings. At the same time other men pump water upon the roofs. The ditch removes

Campfires should never be built on a floor of dead leaves and twigs hemmed in by materials of low kindling temperatures

Bad forest fires have all too often been the offspring of bad campfires

Photos U. S. Forest Service

The result is this frightful monument to the carelessness of man the fuel in the path of the advancing flames. The water on the roofs raises their kindling temperature so that flying sparks may fail to set them on fire.

When a fire starts, it is often possible to smother it by cutting off its supply of oxygen. That is why you may see men beating a fire with brooms or branches, or pouring water or sand upon it. Chemical fire-extinguishers smother a fire by surrounding it with a blanket of heavy gas which will not burn, such as carbon dioxide or carbon tetrachloride.

Exercise. Look up in the library or write to the United States Forest Service for publications on modern methods of fighting forest fires. If your state has a department of forestry, you can find out from it if such measures are being practiced in your state. Report your findings in class.

Guardians of the Forests. During 1933 and 1934 more than three hundred thousand young men were at work in the Civilian Conservation Corps. Most of them were assigned to forest reservations. In less than one year these young men constructed enough miles of truck roads through the woods to encircle the earth at the equator. Such roads at more or less regular intervals through the forest serve as "firebreaks" by providing lanes across which flames cannot pass. They also help men and fire-fighting equipment to get into the woods without disastrous delay.

The same young men also laid fifteen thousand miles of telephone wires, so that news of a fire could be spread rapidly and help quickly secured. They removed underbrush, which is the breeding ground for fire, from a million wooded acres. They developed two thousand acres for airplane landing fields and a great many miles of trails. All told, the C.C.C. more than justified its existence and rightly won a place among the permanent departments of our government.

Exercise. Find out if there is a unit of the Civilian Conservation Corps in your vicinity. If there is, visit it and report on its activities in class.

The United States Forest Service was in existence long before the C.C.C. and long ago proved its worth. Forest rangers are on duty in the national forests at all times. During periods of prolonged drought, when there is more danger of fire than usual, conditions of the atmosphere are carefully watched. During hot, dry weather, men are taken from other duties and held ready for immediate call in case a fire breaks out.

In lookout towers and airplanes, rangers are constantly searching our forests for fire. As soon as a fire is discovered, "smoke-chasers" and equipment are rushed to the scene. It would be difficult to estimate the millions of dollars in forest wealth which the green-clad members of the Forest Service have saved for the people of the United States.

Pest Control in Forests. A second important part of forest conservation has to do with insect and fungus control. While it is entirely practical to use poisonous sprays in small parks, it is much too expensive to undertake such measures in great forested regions. In a few cases forest trees have been sprayed from airplanes, but the cost was very great.

Some fungi may be wiped out, as we saw in Unit I, by destroying a second plant upon which the pest plants live during part of their lives. You may remember the part played by the currant bush, for example, in the case of the

U. S. Forest Service

In lookout towers on many a lonely mountain top
the government ranger stands guard over our forest

white-pine blister rust. In the war upon this deadly disease of trees, state foresters scouted the woods and pastures throughout New England and other infested regions, destroying all currant bushes and related shrubs. As a result many white pines were saved that would otherwise have died.

The spread of insect pests may be delayed in some cases by strict quarantine. In other cases quarantine does not work so well. A more lasting measure is that of discovering some natural enemy that will destroy the pest; provided, of course, that the enemy is not itself a pest. Birds are important natural enemies of insects—a chief reason why all of us should try to protect bird life.

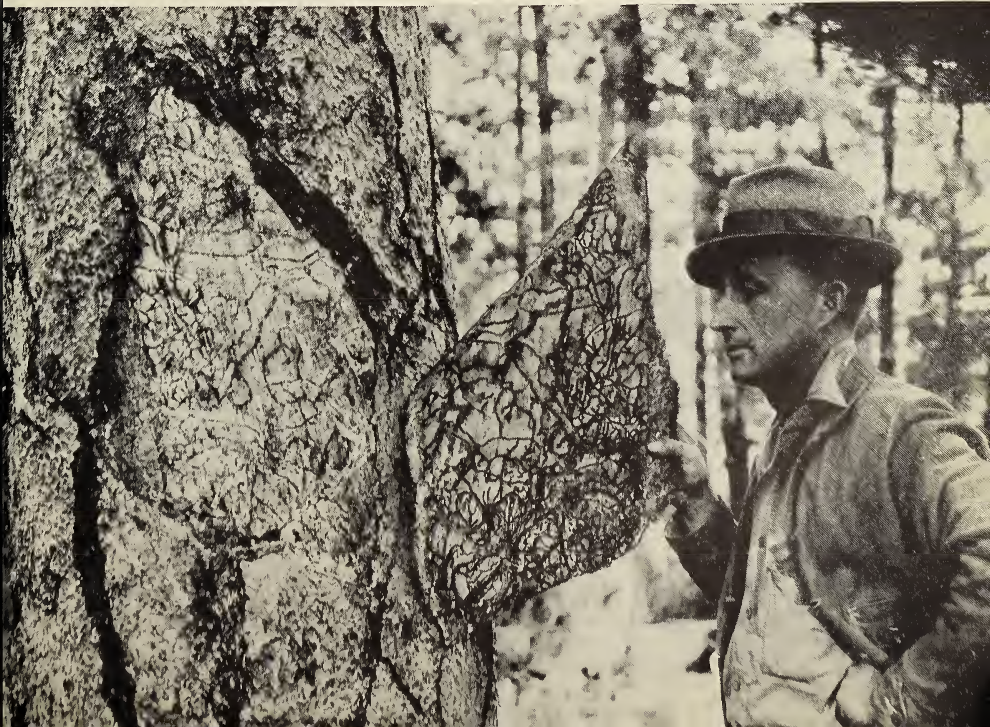
Exercise. Look up in the library or write to the United States Department of Agriculture for publications on the control of pests in the woods. See if you can find out what control measures are being practiced in your state and report on them to your class.

Why Save the Forests? "Why," you might ask, "do we take so much trouble to save our forests? Maybe other products are going to replace those of the forest, as oil has replaced coal for some purposes, as iron has replaced stone and copper for other purposes, and as electric lights have replaced torches and tallow candles. Perhaps we are not going to use so much wood in the future."

Part of the answer to this statement was suggested in the last chapter. Part is suggested in the picture on page 525. Part is contained in figures which show that *until recently we have been using trees just about four times as fast as they are growing.* In one recent year we used ten billion board feet of lumber, most of it from the West.

he pine beetles that riddled this tree with their galleries
are only one of the pests which take toll from our forests

U. S. Forest Service



What other substance could replace lumber for building purposes, furniture, and for its many other uses? There are several possible substitutes for wood, to be sure, but could they be produced as cheaply as wood? Would they be as satisfactory? These are questions that will need much thought if our forests are much further reduced.

Exercise. If there is a lumber-dealer in your community, visit him and see what you can find out about the types of lumber most commonly used in your locality. Which is the most popular variety of wood for general purposes? Where does it come from? Why is some lumber more expensive than other?

The state of New York in 1929 produced nearly two million cords of firewood. You may expect this figure to drop somewhat in the future, perhaps, as coal and oil are more widely used for fuel in rural districts. But where firewood is near at hand it will doubtless continue to be used in large quantities, unless it becomes so scarce that most people cannot afford to buy it.

Do you realize that it may take several acres of small spruce trees to make the paper for one Sunday edition of a metropolitan newspaper? Do you realize that one and a half billion cords of wood are made into pulp each year and used in the manufacture of paper? Rayon and cellophane also depend to a considerable extent on wood. They are made from cellulose, which may be obtained from trees, cotton, corn, or other vegetation. The demand for these products, as well as for paper, is steadily increasing.

Exercise. Make a collection of samples of wood from the trees that grow wild in your region. If possible, get sections from the trunks of small trees with bark attached. Polish the surface of each specimen to show the grain

Here are some of the things the forests give us of the wood and label the purposes for which each type of tree is used.

Not only are forests valuable for their products, but they are also, perhaps, the most valuable protection against soil erosion and destructive floods. They are important, too, in maintaining a steady underground water supply, because water is held around the roots of the trees and much that would otherwise run to the sea is able to soak into the ground.

Forests serve also as game refuges and sanctuaries for wild-animal life. Probably you think at once of Yellowstone Park with its tame bears and herds of bison, but many other forested regions make homes for birds and animals of many kinds. In conclusion, we can do no better than quote the words that Theodore Roosevelt spoke many years ago: "The fundamental idea of forestry is the perpetuation of forests by use. *Forest protection is not an end of itself; it is a means to increase and sustain the resources of our country and the industries which depend upon them.*"

These words are just as true and just as important now as on the day they were first uttered.

Forests are our best protection against soil erosion and floods

U. S. Forest Service

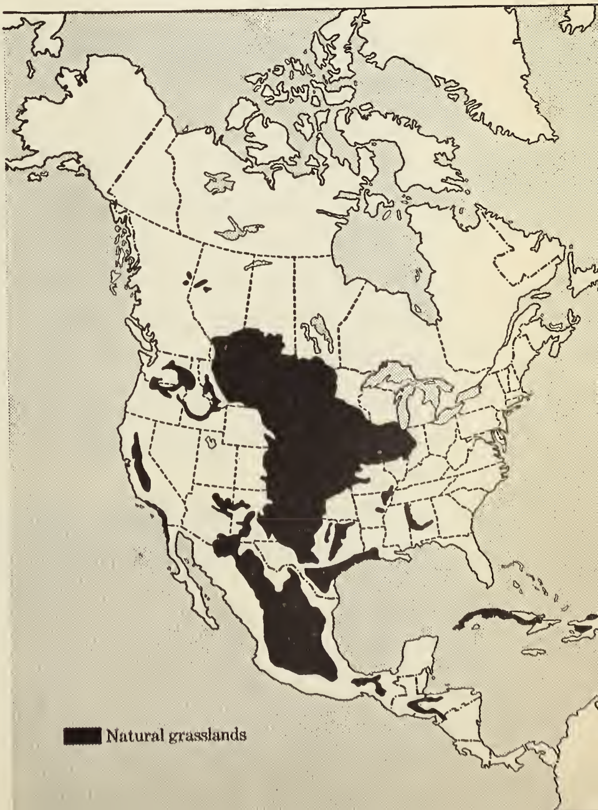
THE PROBLEM OF SAVING OUR GRASSLANDS

What Grasslands Are. The need of doing something to save forested lands has long been recognized. Since President Harrison, in 1892, set aside the Yellowstone National Park Timberland Reserve as the first national forest, there has been a movement to save at least some of the wealth of trees. Meanwhile there has been no similar movement until recently to save the wealth of grass. The grasslands were well on the road to complete destruction before anyone lifted a finger to save them.

Grasslands play as important a role in the balance of nature as forest lands do. They are immensely valuable to man. In the United States alone they once amounted to 850,000,000 acres, about as much land as was originally covered by trees. The map below shows the vast extent of this region.

Natural grasslands (as contrasted with pastures in clearings) are regions in which grasses naturally take complete possession of the ground. Their roots make a thick network throughout the upper layers of soil, and no other plants can compete with them for moisture. Where grass is naturally king, trees can seldom get a footing. Even if they do manage to send

Hundreds of millions of North American acres are the natural homelands of grass



U. S. D. A., Soil Conservation Service

This is how much of the Middle West once looked

their roots into the matted soil, they soon sicken and die because the grass captures most of the water.

The True Prairie. Toward the eastern edge of the North American grass belt, in a zone that ran from Manitoba to Oklahoma, the tall grasses of the so-called "true prairie" once waved in the breeze. In this zone, with Iowa for its heart, abundant rainfall created perfect conditions for grass and for the creatures that lived in it and on it. Today these true prairie lands of tall grass are almost completely turned into plowed fields. The picture above shows a prairie which has been restored by the Soil Conservation Service, and gives you an idea of how a great deal of the whole vast Middle West once looked.

The Short-Grass Plains. West of the true prairie towards the Rocky Mountains, where moisture grows less and less abundant, the tall grasses gave way to the shorter grasses of the so-called "short-grass plains." This region in turn gave way in Texas, New Mexico, and Arizona to the very dry "desert plains grasslands," where the grasses were not only short but few and far between.

Just as the plow destroyed the tall grass of the true prairie, grazing cattle and sheep destroyed much of the shorter grass of the plains. Though grass fires helped in this destruction, too many grazing animals kept for too long a time on the same range were chiefly to blame. The pictures on page 531 show what overgrazed grasslands look like.

Under such conditions the native grasses are thinned out. They are partly replaced by grasses which are of inferior quality for livestock. Once the native cover of vegetation is reduced, running water can get in its deadly work against the soil. The photograph at the bottom of page 531 shows how the topsoil is being removed from a region that was first overgrazed. If overgrazing is allowed to continue in such a region, the soil gets thinner and thinner, the grasses grow poorer and poorer, and livestock finds it harder and harder to get a living.

Why Our Grasslands Have Been Destroyed. Such destruction of our grasslands has been almost universal, and you might well ask why people have allowed it to happen. The answer in the case of the tall-grass country is simple enough. This well-watered region was far too valuable for agricultural purposes to be allowed to remain in grass. With the continent filling up with people who had to be fed, it was absolutely necessary to destroy many square miles of prairie.

The answer in the case of the short-grass country is less simple. It was soon discovered that because of the sparseness and uncertainty of the rainfall on the Far Western plains, agriculture was rather generally an unprofitable business. Very soon the settlers rather generally turned to the raising of livestock. As early as 1800 the livestock industry began to boom, and the romantic story of the cowboy began to be written. That story is practically finished now, and the end is anything but romantic.

With the range lands of the Far West free and unfenced, with few government regulations designed for the good of all the people, private abuses of the grasslands were bound to take place. It was not long before cattle and sheep were chewing the very life out of the land. The chief thought of the owners was to make as much money as quickly as possible, regardless of the damage to the range. The result was that the livestock industry all but killed the goose that laid the golden eggs, and in doing so also all but killed itself.

To be sure, the Western range lands still exist, and they still support livestock. Indeed, by recent estimates they still support 38 per cent more livestock than they should for the good of the land. But the Western range is far from what it once was, as the map on page 533 will show. This map shows that nearly all grassland areas in the western United States have been very seriously injured. It shows more eloquently than words can tell what short-sighted and uncontrolled self-interest can do to half a continent in the short space of half a century.

Grassland Conservation. The problem of grassland conservation is more than the problem of saving such grasslands as are not yet seriously damaged. It is chiefly a problem of re-creating grasslands that have been practically

U. S. Forest Service

Overgrazed range lands mean underfed cattle

The valuable topsoil of overgrazed grasslands is easily removed by rain

U. S. Forest Service

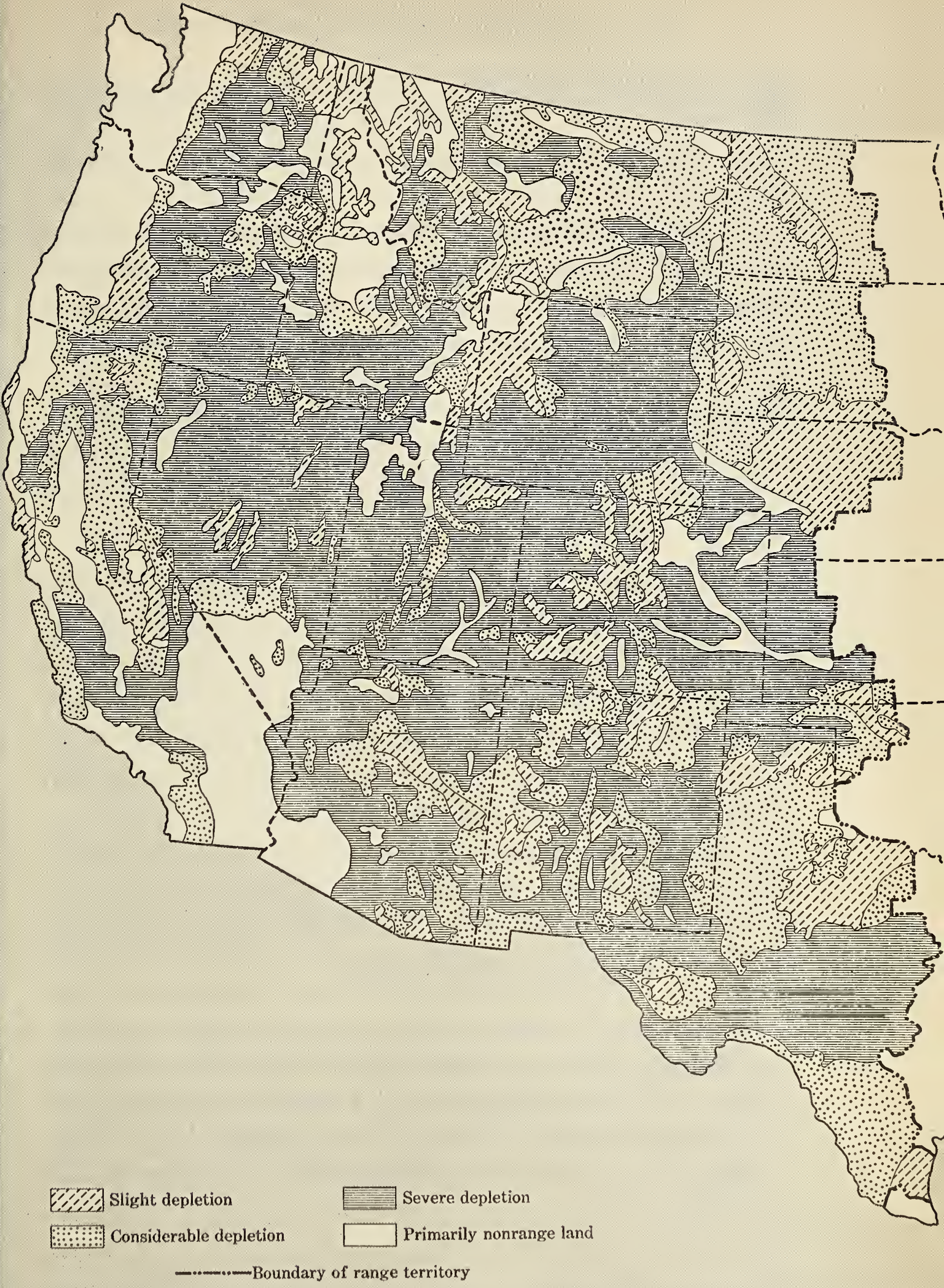
destroyed. It is estimated that over half a billion acres of Western land are now rapidly losing their valuable topsoil by erosion. Without this soil the land cannot support much vegetation. Water runs over it practically unchecked and swells the streams so that floods are occurring with ever-increasing frequency and severity. Wind too picks up the unprotected soil and whirls it in dust storms over the stricken land. Here, you can see, is an extremely serious problem, perhaps the most serious problem that faces our people today.

Fortunately, our state and Federal governments are at last alive to the seriousness of the situation and have begun to do something about it. Though it will probably take much longer to restore the grasslands than it took to destroy them, there is no reason why restoration should not some day become a reality. People who know most about the problem feel that a broad program of grassland restoration and management will succeed in the end. They are agreed that the program must follow the following general plan.

1. The animals now grazing on our natural range lands should be reduced from 17.3 million head to 10.8 million, or 38 per cent of the present total number. When the grasses begin to come back, the herds may be gradually allowed to increase to the capacity of the range.

2. Badly abused range lands should be restored artificially by new seeding. This is an expensive process and can be afforded only in cases of desperate need. Less-depleted range lands should be restored naturally by careful government supervision of grazing.

3. Government-owned grasslands, where supervision is easier, should be increased. At present about half of our total range land is privately owned, and this half contains



This map shows what selfishness and stupidity have done to our Western range lands much the most seriously damaged areas. The good of the country as a whole would be greatly served if there were National Grasslands just as there are National Forests.

4. Special problems of range management should be dealt with by competent government authorities. We need an efficient Federal Grassland Service to match our excellent Forest Service, and we should insist on getting it.

Exercise. The Taylor Grazing Act of 1934 was an important step toward the realization of part of this program. Look up the provisions of this act and discuss them in class.

The social problems of administering millions of acres of land are very great because people rather generally desire immediate gain, whatever the cost in the future. There is always opposition to any proposal that favors tomorrow's profits over today's. The immediate gain from our grasslands, however, grows less and less in terms of wealth and comfort and more and more in terms of poverty and suffering. The selfish gutting of natural resources by a few shortsighted individuals must stop if our good green land is not to be wholly given over to the desert, and our national prosperity hopelessly sunk in want.

Exercise. The Soil Conservation Service and the Division of Range Research of the United States Forest Service have both done important work toward the restoration of our grasslands. Write to these organizations, Washington, D. C., for a list of their free publications on this subject.

THE PROBLEM OF SAVING OUR WILD ANIMAL LIFE

The War against Animal Life. It is easy to see that by destroying the forests and the grasslands, which are the homes of wild animals, we also destroy the animals. How much damage have we inflicted on these helpless inhabitants of the wilderness? How much do we ourselves suffer as a result? What can we do to repair the damage?

Early white settlers found this country teeming with wild-animal life. Some four hundred different kinds of mammals and many more kinds of birds occupied the forested areas. Rivers, lakes, and seas were equally rich in number and variety of fishes. But conditions have quickly changed. As the trees were felled and the prairies plowed up, deer, elk, caribou, and bison were hard pressed to find a place to live and food to eat. Swamps were drained to make room for cultivated meadows, thus making homeless untold numbers of ducks, geese, herons, muskrats, and other marsh-dwelling creatures.

In order to use the water power of our rivers we have built dams across many of them. In so doing we have made it impossible for millions of salmon, trout, shad, sturgeon, and certain other fishes to get from the sea to their breeding grounds in the upper reaches of the streams. As a result, many of them have died without reproducing.

Everywhere wild animals have suffered from the greed and ignorance of a rapidly increasing human population. The pioneer slaughtered wild birds and sold them in the open market, even when a bird dressed and ready to eat meant only a mouthful of food. He trapped animals to the point of extinction for the money he could make. You might think it evident enough that if birds and mammals are killed more rapidly than they can multiply, they must

Massachusetts Division of Fisheries and Game

The "game hogs" of yesterday did their part in reducing the wild life of America to the vanishing point—and apparently were proud of it

soon become extinct. But Americans rather generally have been too busy making a living to worry about how or when or where wild animals reproduced. Not until the supply was almost gone did they begin to wonder if what they had done was right.

Exercise. The Hudson's Bay Company was incorporated in 1670 to obtain furs from the Indians in what is now Canada. Look up the history of this company and see if, on the whole, it used or abused the natural resources with which it dealt. *The Honourable Company*, by Douglas MacKay, is a recent and extremely interesting account of this organization which helped in many ways to shape the destiny of half a continent.

The Fate of the American Bison. It is easy to see that there is not room in this country today for the herds of large animals that lived here during the time of the red man. The American bison, or "buffalo" as it is incorrectly called, was once a part of the balance of nature on this continent. These huge beasts ranged over a third of North America and were numbered by millions in the days before the coming of the white man.

As the white man began to settle in the West, however, bison herds became smaller and smaller. The big clumsy animals were in the way. There was neither room nor food for them, and, besides, their skins and flesh could be sold for cash. "Buffalo" robes were found in every carriage and sleigh and upon many floors. Bison flesh made good food that tasted somewhat like beef. Because these animals lived in herds in the open, they were easy targets. They were butchered in carload lots.

By 1889 the bison had become so scarce that on the entire continent only 1091 were still alive. Of these, 256 were in captivity in parks and 835 were running wild in Canada and the United States. Their value, except as a picturesque reminder of the past, was gone.

About 1900 the idea of Federal ownership of bison herds began to be popular. The Yellowstone Park herd was founded in 1902. The Wichita national bison herd, with fifteen animals, was founded in Oklahoma in 1907. In Canada a still larger herd was created near Wainwright, in Alberta. Under protection in reservations these and similar herds increased until, in 1933, the number of bison in America had risen to nearly eighteen thousand. This rescue of a nearly extinct wild animal is proof that wild life may be protected when sufficient interest is aroused.

T. F. Healy Collection

The buffalo hunt was butchery rather than sport

The American bison will never be as numerous as it was in the past because it can never range over the same vast territory. But there are many acres of land in the western United States and Canada which are not needed for other purposes and which are unfitted for domesticated cattle. Here the bison, if protected and perhaps partly domesticated, may live and multiply. For a long time this animal was the chief source of meat for the Indian. It may someday again become a source of food, if only as an interesting variation from the monotony of beef, pork, lamb, and poultry.

Exercise. Look up in the library or write to the Department of Agriculture in Washington for information on the care of bison on a modern bison reservation. Report in class on "The Life of a Twentieth-Century Bison."

The Fate of the Passenger Pigeon. The fate of the passenger pigeon offers an illustration of the complete disappearance of an animal which was only a short time ago more numerous than any bird now living. This wild pigeon was somewhat smaller than the common domesticated pigeon of our city parks and slightly larger than the still rather common mourning dove. It flew south in the autumn in huge flocks and returned north in the springtime. It covered a range from northern Canada to the Gulf of Mexico and from the Atlantic coast westward to the Great Plains.

All nineteenth-century observers agree about the large numbers of these birds. John James Audubon and Alexander Wilson have given descriptions of flocks so large that they broke limbs from the trees on which they roosted, and so numerous that they darkened the sky as they flew overhead. Lines of birds nearly a mile wide were so long that it took them three or four hours to pass over one spot! These flocks ate enormous quantities of food and were very destructive to regions over which they flew.

When a flock of pigeons appeared in the spring, the whole community turned out to shoot them. Several birds were easily killed at a single shot from a shotgun. They also were snared in huge nets at "pigeon stands," where, tempted by food, they were caught by the thousands. Birds taken at these stands were dressed and sent to market.

Pigeons in such large numbers were undoubtedly a nuisance. They were certainly also a temptation to the man who could sell them for food. Doubtless many of them might have been killed each year without any real danger to the species, if only a few

The passenger pigeon will never darken the skies again

Buffalo Museum of Science

had been left to breed. Our ancestors, however, had neither the grace nor the wisdom to leave these few. The last passenger pigeon died in a zoo in 1914.

The Fate of the Fur Seal. One of the animals that has been slaughtered for its fur is the seal. There are several different kinds of seals and sea lions, some of which have very little hair or fur. But the fur seal which lives in the waters of the northern Pacific and upon the Pribilof Islands off the coast of Alaska is covered with a beautiful fine, soft brown fur. Scattered through the fur are long stiff hairs which protect the softer fur while the animal is in the water, but these hairs may easily be plucked out when the fur is prepared for market. The seal is a comparatively large animal, and its skin, though soft, is tough. These two characteristics make it very valuable.

This bull seal with his harem of cow seals and their pups was photographed on one of the Pribilof Islands off the coast of Alaska

Harry J. Christoffers

Fur seals spend the greater part of the winter in the ocean and may roam as far as California and Japan. When spring comes, they find their way north again to the Pribilof Islands, which have been their one and only breeding ground for countless generations. During the nineteenth century hunters from Russia, Japan, Canada, and the United States found it profitable each spring to kill these animals in large numbers in the waters near these islands.

The seals were usually speared or shot in the water, and a sizable proportion of the dead sank before they could be recovered. In many cases the hunters could not tell which of the frightened animals were males, which females, and which young. Between 1867 and 1869 more than three hundred thousand seals were killed in Alaskan waters, and this rate of slaughter continued until about 1900. In 1910 only about one hundred and thirty-two thousand fur seals remained in the entire world.

In 1911 a treaty was signed by the United States, Great Britain, Russia, and Japan, making the Pribilof Islands a fur-seal reservation under the control of the United States government. It was agreed that all four countries were to share in the annual proceeds from the reservation. It was also agreed that nobody should be allowed to kill a seal that was swimming in the water.

A study was made of the life history of the seal. It was learned that as the animals came upon the islands to rear their young, the old males came first. Each male, or "bull," chose his own particular territory, and upon this area he allowed no trespassing. The most powerful individuals gained what seemed to be the most desirable sites near the shore. The young half-grown bulls were forced to take what was left, some distance inland.

In early June the females appeared. A bull near the shore might secure from ten to twenty females to live within his exclusive domain. The young which were born after the females came ashore remained with their mothers all summer. Meanwhile the males spent most of the time fighting among themselves.

When the men in charge of seal protection had learned these facts, they decided that some of the young males might be killed without in any way disturbing the life of the "rookery," as the breeding place of fur seals is called. Indeed, a scarcity of males would simply mean less fighting and fewer deaths. Accordingly, only young male seals are killed today to make fur coats. In the twenty years between 1910 and 1930 the population of the seal rookeries on the Pribilof Islands increased from one hundred and thirty-two thousand animals to nearly one million.

The Fate of the Salmon. Salmon once were numerous in nearly all our rivers on both the Atlantic and the Pacific coasts, but our chief supply now comes from Alaska and the rivers that empty into Puget Sound. In early spring these salt-water fish, in schools of millions, swarm up the rivers to breed. They jump the rapids and pass over seemingly impossible obstacles. When they arrive at a place where two streams meet, all strangely choose one stream, although to a human observer the other looks equally inviting.

This salmon is on his way up the Columbia River to breed

Bureau of Reclamation

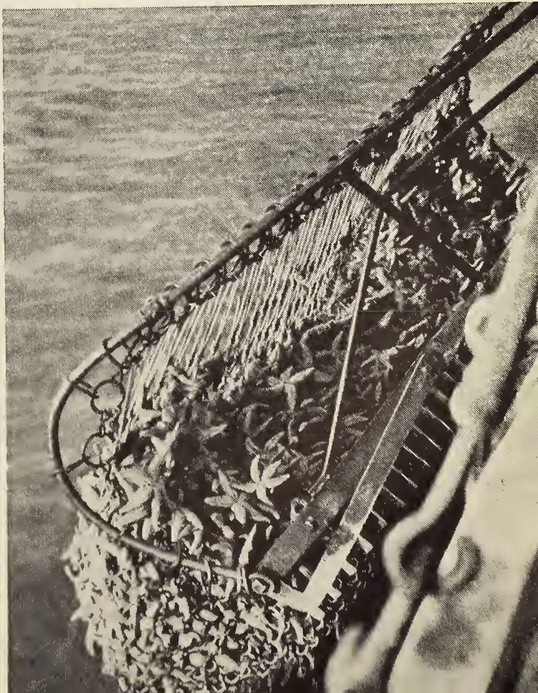
It has been found that they always choose the coolest part of a stream, which is also the part that is richest in dissolved oxygen. The oxygen is apparently especially important to them at breeding time, not only for breathing but also for hatching the eggs and supplying them with air. Indeed, the strange yearly journey of salmon from the sea to the headwaters of streams is thought by some scientists to be a journey in search of oxygen.

The salmon goes even farther than most other migratory fish, straight to the streams near the mountaintops. These mature salmon spend from four to five months a year in fresh water, and most of them die there. A few return to the ocean. Since each female lays several thousand eggs, it is easy to see that there are many young fish. All of these that are destined to mature must get to the sea.

Why has our supply of salmon, as well as of other migratory fish, diminished with the years? Have we disturbed conditions under which these fish have lived? The answer, of course, is Yes. First of all, wholesale methods of catching salmon as they come upstream has seriously reduced the number of these valuable food fishes. Second, there are dams in the rivers which we have built to supply water power. Unless special runways are built, it is difficult or even impossible for the fish to pass by some of these dams. This, of course, means a great loss, because many of the mature fish die before

Dredging for starfishes is an effective way of reducing this enemy of the oyster

U. S. Bureau of Fisheries



spawning, and many of the young fish die in attempting to get downstream to the sea.

Exercise. Read *Salar the Salmon*, by Henry Williamson. It is so vividly written that you will feel like a salmon before you have finished the book.

The Conservation of Wild Animals. Conservation of natural resources becomes important to the average person only when he begins to feel a shortage of supply. Accordingly, conservation of wild life as a national policy and as a topic of popular interest did not appear until about 1890. Within the last fifty years our efforts for wild-animal conservation have ranged all the way from elephants to oysters and have included a recent attempt at preserving the great whales.

The United States Bureau of Biological Survey came into being in 1885. It now enforces conservation laws relating to game and fur animals, to the protection of birds on reservations, and to the migratory-bird treaty with Canada. It maintains preserves and sanctuaries for birds and big game. It carries on research and experiments relating to fur-farming, game-farming, and the reindeer industry in Alaska. It serves as a general clearinghouse for information on wild-life conservation.

The Forest Service protects the wild animals in national parks, while the United States Bureau of Fisheries is responsible for the protection and breeding of food fish, including shellfish. Of course shellfish (clams, lobsters, oysters, and scallops) are not fish, but they live in the water and their conservation is just as important as that of the fish we have been discussing. The Bureau of Fisheries also cares for the fur-sealing on the Pribilof Islands.

In addition to these agencies of the Federal Government,

U. S. Bureau Biological Survey

his beautiful trumpeter swan, member of a nearly extinct species, is living in peace on a bird refuge in Montana

most states and some towns have game wardens whose duty it is to see that local regulations are maintained. They must see that hunters and fishermen have licenses for which they have paid, and that they hunt and fish only at certain seasons and under certain conditions.

In nearly all localities "spring shooting" of animals is now forbidden, because spring is the breeding season and shooting then means heavy loss of young. "Night shooting" of birds is also prohibited in many places, because birds migrate in largest numbers at night. Certain animals in danger of being entirely destroyed may not lawfully be killed at any time, while the "open season" for others is only a few days in late fall or early winter. Similarly, the fishing season is limited, and only fish larger than a certain minimum length may be taken. Commercial shooting and the spearing and netting of fish are also strictly regulated where not entirely prohibited.

Exercise. Look up the fish and game laws in your state and be ready to discuss such questions as "Are any animals listed as having no open season?" "Are the seasons on most animals long or short?" "Are there closed seasons on the female and not on the male?" See if you can explain why the laws you find are necessary.

In addition to the many public agencies there are countless private sanctuaries for birds and other animals, and many organizations interested in conservation of wild life. Golf courses have come to be used commonly for bird sanctuaries. Many large estates are "posted" against hunting and fishing at all times, and thus serve as homes and safe breeding grounds for birds and mammals.

Organizations formed for the protection of wild life include the National Association of Audubon Societies, the American Nature Association, the Isaac Walton League, the American Forestry Association, and many others. Perhaps your community has a branch of one of them. If so, what do you know of its work? If all of us should wholeheartedly support such organizations, there would be no problems of how to conserve our plant and animal wealth.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The great difficulty of practicing forest conservation is that trees cannot be used and saved at the same time.

2. Through forest conservation all land that can possibly be spared from agriculture has been planted with trees.

3. Lightning starts most forest fires.

4. The greatest enemies of our forests are insects that feed on various parts of trees.

5. Owing to the newly invented substitutes for wood, we now have about four times as much newly grown timber each year as we can use.

6. Because grasses are such hardy plants they need and receive less care than do trees.

7. Fire is the greatest enemy of our forests and grasslands.

8. Destruction of the Western grasslands has no bearing on soil erosion because the rainfall on the Western plains is too slight to produce any erosion.

9. Since most of our meat comes from South America, it is not necessary to practice conservation of our own grassland areas.

10. Bison could not exist under modern conditions, and it is just as well that our forefathers destroyed them all.

11. The passenger pigeon was a pest bird and was destroyed for that reason.

12. Today no fur seals may be killed when they have come to the Pribilof Islands to breed.

13. Dams across streams help to conserve our supply of salmon by preventing these fish from entering the streams, where most of them would die.

14. Under present conditions, no open season on any fish or game should be allowed in this country.

Questions for Discussion

1. What are the most common causes of destructive forest fires? Can you support your answer with concrete examples?

2. How does the wild-animal life of your region today differ from what it was a generation ago? Consider birds as well as ground life. Perhaps some older people at home can help you get a better understanding of conditions in the past.

3. Should wild animals be preserved in national parks such as Yellowstone Park, in Wyoming, or the Carl Akeley Park, in Africa, even when these animals are of no possible economic value?

Things to Do

1. We have suggested in this chapter that forest management in the various countries of Europe differs greatly from that in this country. You may wish to make a special study of these differences and to discuss whether or not Europe has a more sensible outlook upon the importance of lumber and forests than we have in this country.

2. Start a tree nursery in your school, with the idea that trees will later be planted where they may grow to maturity. Some states furnish young trees at little or no cost to people who will use them wisely. Investigate the situation in your own state and see whether this service is provided there.

3. See if you can find any dens of small animals in your neighborhood. Perhaps you would like to photograph them. You can probably find a book in the library that will explain how you can secure pictures of animals in their native state.

4. Read in class some descriptions of pigeon-trapping, bison-hunting, whaling, or other forms of sport or industry which were written before the twentieth century. See if you can find any differences in the general attitude toward such slaughter then and now.

5. Look up information about our migratory-bird treaty with Canada and report on it in class.

6. Make a special study of the whaling industry and find out whether there is any danger that whales will become extinct. You may wish to carry this study into other fields and find out what animals have actually become extinct within the last century.

7. Make a special study of the migratory habits of the shad and compare them with those of the salmon. Has the shad suffered as much as the salmon from the attacks of man?

CHAPTER NINETEEN

How Can We Conserve Our Minerals and Soils?

THE PROBLEM OF METAL CONSERVATION

Mineral Resources Are Not Inexhaustible. Just as it was with the help of minerals that men were able to move from savagery to civilization, so it will be with the help of these materials that man will climb farther up the ladder of achievement. "Then," you might say, "why worry? Rock and soil are everywhere, and they cannot be used up." If you said that, you would be expressing a belief which works out very badly in practice. In the past, men have used the mineral resources of the earth with unrestrained extravagance. Indeed, they are only now waking up to the fact that in doing so they have committed a blunder which has led to some of the most serious problems of the modern world.

The Metal Supply. From your studies in Unit II of this book you know that metals are the very foundation of our modern civilization. You know that the available deposits of even the most abundant of them are relatively rare in the rocks of the earth's crust. Deposits of such metals as iron, aluminum, copper, lead, and zinc have been built up in extremely limited areas through the ages. Anybody who thinks about it at all will realize that such deposits cannot last forever. Once exhausted they are gone—for all practical purposes—forever.

In Unit II you also learned that we are already suffering from a shortage of certain metals. You learned that we can

Asahel Curtis

Good farmers get many crops from the same land

No matter how expert the miner is, his mine will yield only one crop

Coal Age

expect to suffer even more in the future. The farmer takes a crop of corn from the fields and knows that more corn will grow in the future. The miner takes a crop of metal from the earth and knows that the mine is just that much nearer to ruin. What can be done about this situation? Is there any way for our machine civilization to grow without at the same time committing suicide?

It is an interesting sidelight on the recklessness with which we have used our wealth of metals to observe that there has never been an accurate survey made of the total supply of a single metal. We do know in general that the known supply of high-grade iron and copper ores in the United States cannot be expected to last more than half a century longer at the present rate of use. "But," you might say, "are not new deposits continually being discovered? How about the *unknown* supply of metals?" Let us see.

Modern Prospecting for Metals. Most of the world's valuable mineral deposits were discovered by accident. Some of them (such as the copper ores of Michigan) have been mined for so long that nobody today knows who first stumbled upon them. We do know, however, that many of these deposits extend to the surface of the ground and might easily have attracted the attention of a moderately observant passer-by.

We generally think of a prospector as a grizzled old man with a pick and a burro and a love of roaming. As a matter of fact, many mineral deposits have been discovered by such men. Armed with perseverance and a "nose" for ore, the old-fashioned prospector could find a mineral deposit if it made any trace on the surface. But he was quite unable to explore the regions that lay below the reach of his eye and pick.

Robert Yarnall Richie

These men are prospecting for oil by observing how artificial earthquake waves (produced by high explosives) pass through the ground

The result was that with time the most valuable surface ore deposits were located, and the prospector had to be content with smaller game. Though his dreams never diminished in size, his findings did. The discovery of valuable deposits of metal ores in America reached its highest peak in 1880, and since about 1910 practically no new deposits have been found.

Although the discovery of new deposits of metal ores went abruptly down near the beginning of the twentieth century, the discovery of new oil fields went abruptly up. To a large extent the reason for this is that the oil industry adopted scientific methods of prospecting, but the metal industries clung to the crude methods of the old-fashioned prospector.

The sciences of geology and physics have contributed methods and instruments which can probe into the depths below the surface of the earth. Artificial earthquake waves, for example, can be sent through the ground by the discharge of high explosives. Sensitive instruments recording these waves can tell something about the materials through which they moved. This and other modern methods have been highly developed in prospecting for oil, but little used in the search for other kinds of mineral wealth.

It may be that when more scientific methods of prospecting are more generally applied to the metals, some new valuable deposits of metal ores will come to light. We cannot assume, however, that such will certainly be the case. *The chief problems of metal conservation are not to be solved by the discovery of new riches but by more efficient use of the riches we already possess.*

Exercise. Read *All about Treasures of the Earth*, by F. A. Talbot, for an interesting story of the discovery and development of our mineral resources.

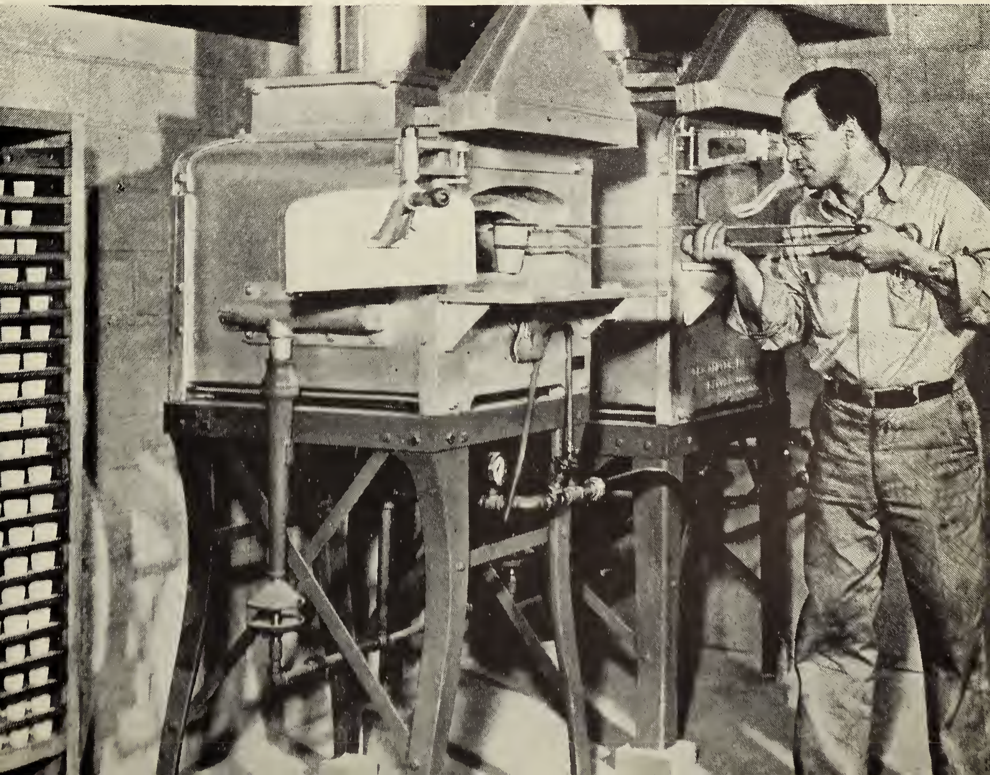
Conservation at the Mine. Since metal ores occur in association with worthless rock, the miner must select the one and reject the other. It is easy to see that under careless mining conditions much good ore will be thrown out on the dump. Through careless methods of extracting the ore and timbering the shafts and tunnels, cave-ins may occur which ruin great blocks of high-grade ore and in some cases the whole mine.

Wasteful mining methods have been the rule rather than the exception in this country. Blessed with a great abundance of nearly all the essential metal ores, we have recklessly laid waste our treasure houses in the ground. Fortunately we are beginning to realize that even the vast mineral resources of America are limited. Mining methods have greatly improved in the last few decades. Not only are we getting more out of the new workings of mines, but we are going back to the old workings and dumps and recovering values that were thrown away or overlooked before.

Conservation at the Smelter. Since in most metal ores the metals are chemically combined with other elements, scientific methods must be used to render the materials fit for use. Here, as in mining, modern knowledge is steadily working on the side of conservation. Not only are we steadily getting more and more of the valuable metals from their ores, but we are learning to improve the qualities of many metals by combining them with other metals in alloys.

This man is analyzing (assaying) an ore, to find out the exact amount and value of the metals it contains

U. S. Bureau of Mines



Exercise. Review Chapter Five and refresh your mind on how iron is alloyed so that it becomes more resistant to wear and to rust. Do you believe that the alloying of iron with other metals significantly helps to conserve the supply of this most important metal?

Metallurgy is the science that deals with the preparation of metals for use. It was this science that discovered that alloys of metals may be made which will wear better and therefore last longer than the individual metals of which the alloys are composed. The contribution of metallurgy to conservation, however, only began with this discovery.

The most important contribution of metallurgy has to do with the use of ores which only a few decades ago were considered worthless. These *low-grade ores,* as they are called, are far more abundant than the high-grade ores, which until just recently were practically the only ores mined. Through metallurgy we are learning how to extract metals at a profit from rocks which only a short time ago could only have been mined at a great financial loss.

This scrap iron, salvaged from worn-out machinery, will be resmelted and used again

William Rittase

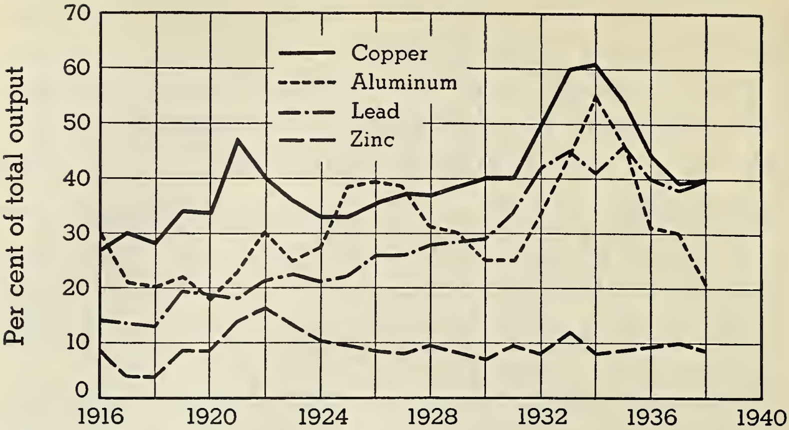
It is estimated that the vast iron deposits of the Lake Superior region contained about 3½ billion tons of iron ore which runs as high as 50 per cent iron. For many years it was unprofitable to mine ores that ran any lower in iron than 50 per cent, and even now no lower-grade ores are being mined in this area. But, thanks to metallurgy, ores as low as 36 per cent iron can be and in some places are being mined and smelted at a profit. Some 276 billion tons of such lower-grade ore are lying in the ground in the Lake Superior district, ores which will someday be used.

The same thing is true of the ores of copper and many other metals. By finding ways of using the lower-grade ores, metallurgy vastly increases the usable supply of these valuable materials.

Exercise. Look up in some book on minerals and mining the methods used to recover copper from extremely low-grade copper ores. Report your findings in class.

Use of Scrap Metals. In the United States alone, millions of tons of metallic objects are worn out or broken with use. Much of this metal finds its way to dump heaps. In large part, however, this metal can be resmelted and made into new machines and, to a growing extent, is being so used in all countries of the world.

It has been estimated that more than a billion tons of iron have been produced in this country since the white man took it from the red man. Of this, some 35 per cent is estimated to have been lost by rusting and from being made into objects from which the metal cannot profitably be recovered. This leaves about 650 million tons which might be recovered and used again. Perhaps the most important part of metal conservation is the reclaiming of this tremendous supply of so-called "scrap." That we are doing this



This chart shows how much of our total production of four important metals is secondary

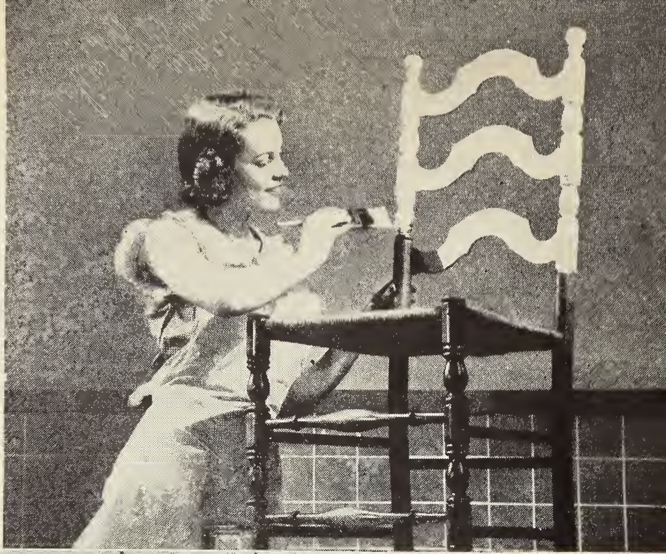
is shown by recent figures on the production of steel in the United States. At present about two thirds of our steel is made from newly mined iron ore; the other third comes from scrap.

Metals extracted from new ore are referred to as *primary* production; those produced from scrap are called *secondary.* The chart on this page shows what large percentages of secondary production exist in the case of several important metals other than steel. Do you see what tremendous savings in our metal consumption the use of scrap metal brings about?

Use of Metal Substitutes. All metals, of course, cannot be so easily reclaimed as iron, copper, and aluminum. Lead and zinc, as you can see from the chart, are less easily saved, chiefly because they are used so widely in paint. Can we not find some other substances to use in place of metal in products which are destroyed by use?

The development of so-called "plastics" and many related materials has already led to a saving of our natural

Enamels made from nonmetallic materials are cutting down the use of paints made from lead and zinc



Many fountain-pen and pencil barrels are made of the plastic "pyralin"

Photos from E. I. du Pont de Nemours & Co

"Cellophane" has challenged the supremacy of paper and tin foil as wrapping materials resources. A host of articles formerly made from ivory, tortoise shell, or amber are today made from such plastics as "bakelite," "lucite," and "pyralin." (See photographs on page 559.) "Nylon," because of its greater strength and elasticity, is destined partly to replace cotton and wool. "Cellophane" has already cut down the use of paper and tin foil as wrapping materials. Artificial nonmetallic lacquers and enamels are partly replacing paint made from lead and zinc.

These artificial products are made by combining certain of the elements from natural materials which are for the most part cheap and abundant: coal, wood, air, and water. Though their use up to now has led chiefly to the conservation of nonmetallic materials, their future development will doubtless lead to an increased saving in metals as well.

Exercise. Read up on "plastics" in the library and then take stock of the "plastics" which have already found their way into your home and automobile. How many of these materials do you believe are taking the place of metals in your life?

THE PROBLEM OF CONSERVING THE ENERGY MINERALS

The Seriousness of the Problem. Metals, of course, cannot alone insure the safety of our modern machine civilization. Energy is needed to run the machinery, and most of this energy at present comes from coal and oil. Like the metal-bearing minerals, the energy-yielding minerals are definitely limited in extent. Unlike the metal-bearing minerals, coal and oil when used leave no scrap that can be used again. They bestow their gift of heat and power but once.

Civilization as we know it would collapse if the energy minerals should suddenly cease to exist. Since we are rapidly using up the world's supply of these minerals, it is easy to realize that the problem of their conservation is extremely serious. Modern prospecting, as we have seen, is discovering new sources of petroleum. These discoveries, however, cannot go on forever. Meanwhile our need for energy increases. How to meet this need in the future is one of the gravest problems of modern man, and one that should be faced at once.

Use of Low-Grade Coal. Cannot our supply of energy minerals be extended by the invention of processes for using low-grade materials, as in the case of the metal ores? The answer is Yes, but not to nearly so great an extent. Turn back to the map on page 199 and you will see the location of the low-grade coal deposits of the United States. Notice that they are far from the great manufacturing centers, where most coal is used today. Doubtless in the future the energy of these coals will be used, probably by burning the coal at the mines and carrying the energy in the form of electricity to the places of use. Even assuming that this will be done, one thousand—at most, two thousand—years will probably see the end of coal.

Conservation of High-Grade Coal. The deposits of high-grade coal (bituminous coal and anthracite) will doubt-

Black smoke means poor combustion and a waste of fuel

Galloway

less be gone long before then, particularly if we use and waste coal at the present rate. About one ton of coal is now wasted for every three tons that are mined—a terrible tax on our carelessness.

Fortunately, we are now aware of the stupidity of this recklessness and have taken steps to avoid it. Mining methods are becoming more scientific and therefore more economical. Railroads are becoming more efficient and are burning proportionately far less fuel than in the past. Power plants too have learned to make coal go farther than formerly in the production of electric energy, and many other coal-burning machines and factories have improved their operating efficiency. All this will help to extend the life of the most valuable source of energy in use today.

Exercise. Visit a coal-using factory near your home. See if you can learn how much waste occurs in the use of the coal or the energy taken from the coal. How might this waste be eliminated?

Burning oil wells are a frightful waste of wealth

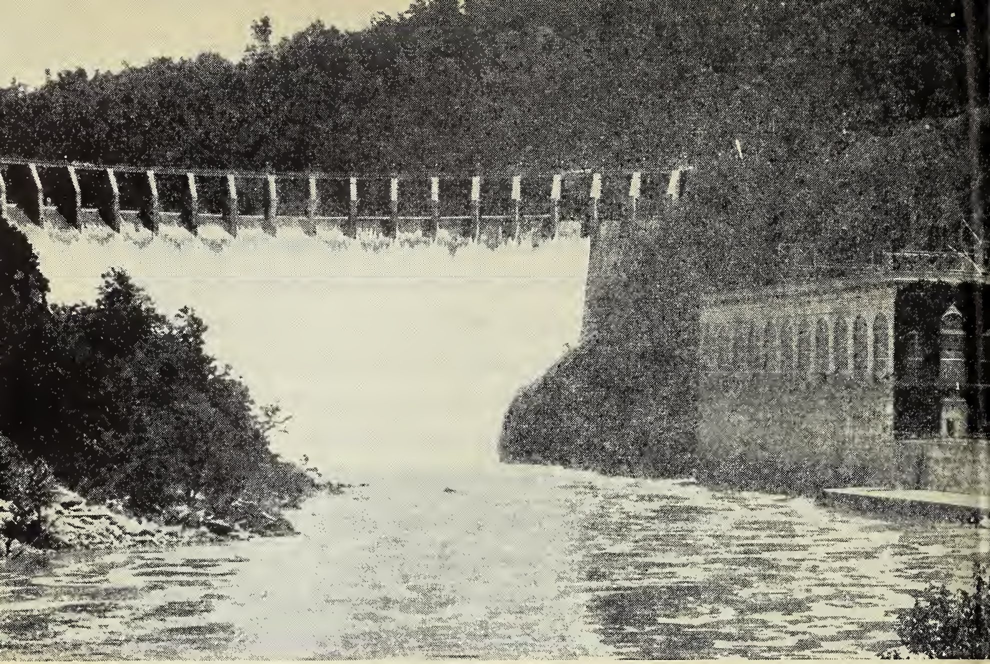
Galloway

Conservation of Petroleum. Petroleum, like coal, is a rapidly vanishing blessing, and a few hundred years may see the last drop of it go up in smoke. Like coal, petroleum is being recklessly thrown away; but not so recklessly as formerly. Improved methods of drilling bring more of the "black gold" to the surface from the reservoirs in the rocks below, and much less oil is lost in "gushers" and burning wells. Machines for using petroleum are steadily growing more efficient, but unfortunately are also growing more numerous. As a matter of cold fact, nothing can be done to escape the day when this valuable fuel will have been completely consumed. We can only hope through conservation to postpone the evil day as long as possible.

Fortunately there are mountains of shale rock in Colorado, Wyoming, and Utah which will undoubtedly help to bring about this postponement. These are the so-called "oil shales," which as yet have been practically untouched. Some of these rocks are so rich in petroleum that they can be made to burn with a flame, and the richer oil shales can be made to yield as much as a barrel of oil to the ton. It is estimated that there is enough high-grade oil shale in America to supply our liquid fuel needs for perhaps one hundred and fifty years.

Exercise. Look up *Petroleum and Coal, the Keys to the Future*, by W. T. Thom, Jr. It will give you much useful and interesting information on the future development of our two most important energy-yielding minerals.

The Energy Supply of the Future. From what has been said it is easy to see that someday substitutes for coal and oil must be found. We shall undoubtedly have to make more and more use of such nonmineral fuels as alcohol (which can be made cheaply from corn). We shall probably learn to use the energy of the wind and the direct rays of the sun with more efficiency than we have been able to use them in the past. We shall possibly learn how to harness the tides. Whatever else we do, we shall certainly increase our use of the energy of streams.



H. Armstrong Roberts

Hydroelectric power plants will increase as coal and oil decrease

In Unit III we saw that running water is already being used to generate electricity. Owing to competition with cheap fuels, however, water power has not yet been highly developed in this country. It is estimated that only 10 per cent of the total energy output of this country now comes from running water. As coal and oil grow scarcer and more expensive, this percentage will certainly rise. Hydroelectric plants will be built on rivers which are now considered too remote to be profitably used for power.

Though water is surely destined to rise in importance as an energy-producing mineral, it can probably never take the place that coal and oil now hold in the industrial world. As long as man lives on earth he will have to seek out new sources of energy. Meanwhile he had better do what he can to conserve the sources he now has, because he may never find any better ones.

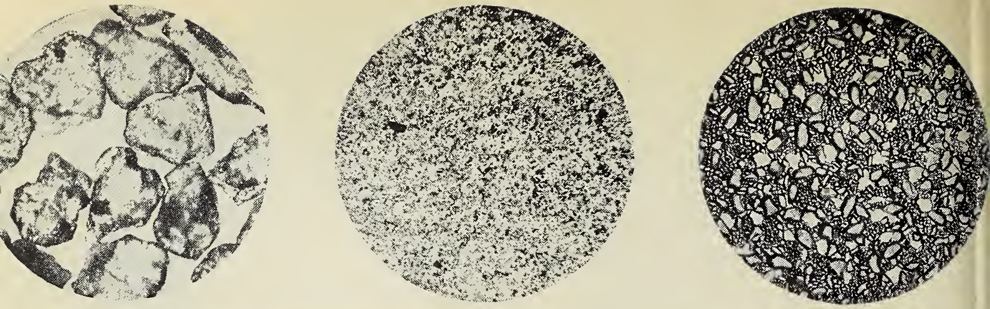
THE PROBLEM OF CONSERVING THE SOILS

The Everlasting Need of Good Soils. Just as metals and fuels are needed to maintain the machines of the modern world, good soils are needed to maintain the men who run the machines. No matter how far man progresses in the art and science of using the world, he will never progress to the point where he no longer needs to eat. As long as he needs to eat, he needs good soils to provide the food.

The Kinds of Soils. In earlier work in science you have probably learned that *all soils which are fit for agriculture are made chiefly of fine particles of rock mixed with water, air, soluble minerals, and decayed plant and animal matter.* Such soils may be subdivided into three main types on the basis of their chief ingredients.

Sandy soils are made up chiefly of broken pieces of the mineral quartz. They are coarser than most soils in texture, and they dry quickly after a rain. Unless such soils are relatively fine-grained, the rain water passes through them rapidly and washes out the soluble minerals which plant life must have for food. Even in the case of the good sandy soils of central Florida, orange-growers must spend a great deal of money for fertilizers to replace the mineral foods which are yearly "leached" out of the soil by the rains.

Clayey soils are made up largely of chemically altered particles of the mineral feldspar. These particles are much smaller than the particles of rock in a sandy soil. Surrounding each one is a film of water; and since there are so many of them, a soil that is mostly clay is likely to be a wet soil. Sometimes the particles of a clayey soil are so compact that plant roots can hardly penetrate the spaces between them (see illustration on page 566). For this reason and also



Sandy soils (left) are coarse-grained and composed chiefly of quartz grains. Clayey soils (middle) are fine-grained and composed chiefly of chemically changed feldspar and water. Loamy soils (right) are medium-grained and composed of a mixture of sand, clay, and humus[1]

because they are hard to plow, pure or nearly pure clayey soils are not good soils.

Loamy soils are composed of a mixture of sand, clay, and humus. "Humus" is the name given to the partly decayed remains of plant and animal matter in the soil. This material supplies the minerals needed by plants. Soils that lack humus are poor soils, but those with too much humus are likely to be acid. Loam is the best soil for most cultivated crops, not only because it contains the right amount of humus, but also because it is open enough to admit the air which is needed by the roots of plants. It also holds the right amount of moisture.

Exercise. Explore the fields near your home and if possible get samples of sandy, clayey, and loamy soils. Spread a small amount of each sample on a glass slide and examine it under a microscope. How do the samples differ from one another?

How the Problem of Soil Fertility Developed. When there were many more acres of possible farming lands than there were men to cultivate them, the problems of finding good

[1] After T. L. Lyon, *Soils and Fertilizers*, published by the Macmillan Company.

soil and keeping it in good condition were not serious. If the land "ran out," as the saying went, the early farmer had simply to move on to other lands that were better. But the time came in many of the more desirable parts of the world when men became more numerous than good farm lands. Such lands then became more valuable, and men had to begin to care for them properly.

The earliest-known agricultural civilizations, such as those of the ancient Babylonians, Assyrians, and Egyptians, began upon the flood plains of the world's large rivers. Each spring the rivers overflowed their banks and dropped layers of fine rich soil brought down from the higher land. This soil contained mineral substances dissolved from the rocks, and also humus. Without any effort on their part, the farmers in the river valleys had fine rich soil in which to grow their crops.

As the population of the world increased and it became necessary to farm the lands that lay beyond the flood plains

The yearly flooding of the Nile keeps its valley fertile

Crown copyright reserved. Royal Air Force photograph

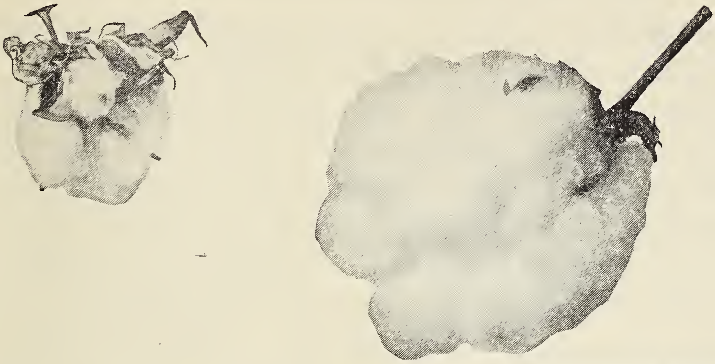
of rivers, something had to be done to maintain the supply of the soluble mineral matter that makes up so important a part of all good soils. Plants use these substances in growing, and there may be as many as sixteen different chemical elements in a single plant cell. Except for carbon, which comes from the air, all the necessary mineral materials must be provided by the soil.

In a forest or an uncultivated field, where plants grow and die and where animals eat the plants and later die on the same soil, these mineral substances are returned to the soil whence first they came. Except for changes caused by running water, the mineral content of the soil tends to remain the same.

By way of contrast consider a cultivated field of wheat. The wheat plants grow in the soil and take minerals from it to build the tissues of their bodies. The plants are then

This farmer is plowing under a field of soy beans. Valuable materials will thus be given back to the soil to nourish the melons which the farmer intends to plant in the spring

harvested and sold, and the land loses part of its mineral wealth. This process, even in the richest lands, cannot go on indefinitely if good crops are to be grown. When we take from the soil, we must repay the soil or suffer. One way of repaying is through the use of fertilizers.



American Potash Institute

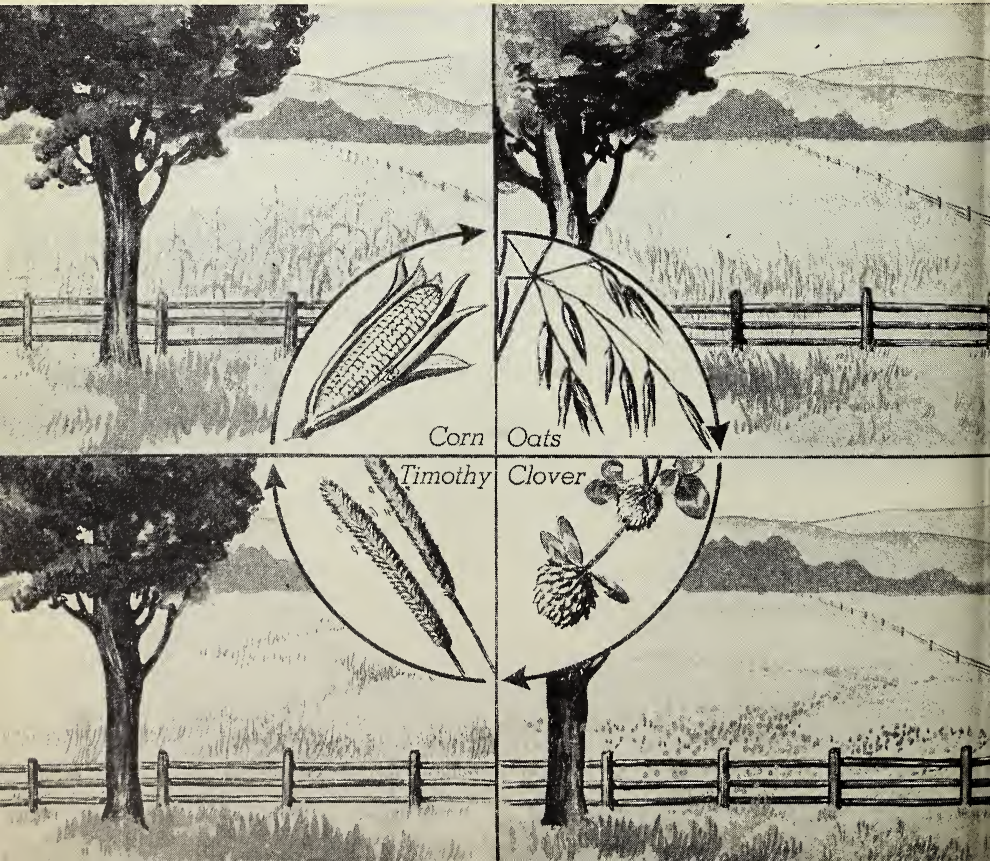
Potash added to the soil which produced the cotton boll on the right accounts for its larger size

Use of Fertilizers. The first type of soil fertilization was probably the use of manure from domesticated animals. This material has its origin in plants and therefore contains the chemical elements necessary for plant growth. Later on, men learned to plow weeds into the soil to provide humus, or "green manure."

The *compost heap* also became a handy help to soil fertility. This consists of both plant and animal refuse piled up and allowed to decay. When partially decayed, it is spread upon the fields. Compost, like manure, gives back to the land the minerals that have been taken from it by growing plants. Farmers also learned very early that lime may be added to the soil to correct an acid condition. Lime is contained in ground bones, bone ash, clamshells, and crushed limestone.

No other advances in the method of fertilizing soil were made until, in the last century, guano beds were discovered on islands off the western coast of South America. As we learned in Chapter Six, these guano beds consist largely of the droppings of birds that live along the rocky cliffs. When guano is spread upon the land, it increases the phosphorus in the soil, an element which is absolutely necessary to the growth of food plants. Phosphorus for fertilizer is now obtained chiefly from bones and phosphate rock. Perhaps you remember from Chapter Six that domesticated plants must also be fertilized with nitrates and potash. Without the steady use of these mineral materials the fertility of our farm lands would rapidly disappear.

This four-year plan of crop rotation is common in New England



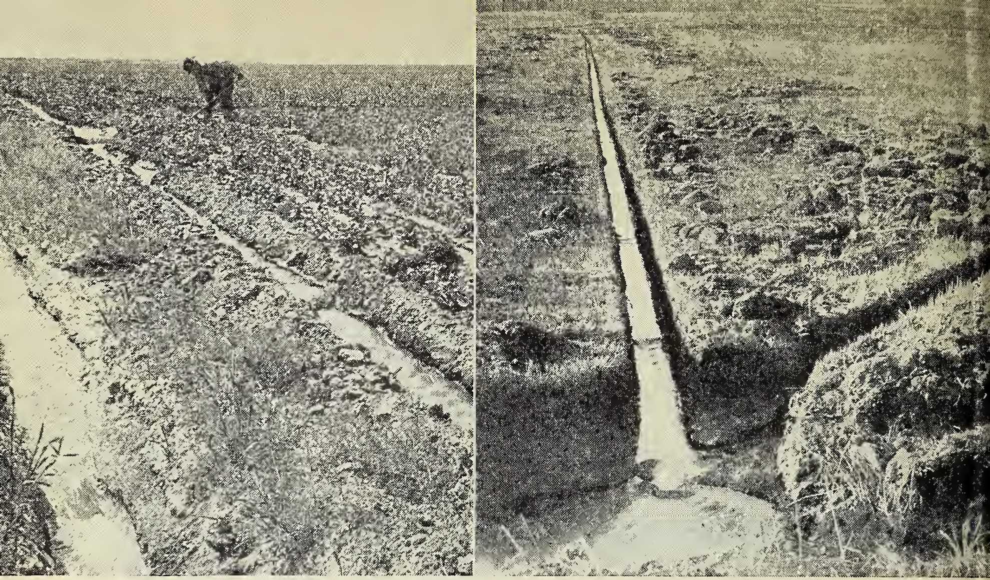
Exercise. Find out from a farmer in your neighborhood what kind of fertilizers he uses on his land and why he uses them. What would happen if he stopped using them?

Use of Crop Rotation. The poet Vergil, two thousand years ago, advised the Roman farmers either to let their land lie fallow every other year or to change the type of crop from year to year. Farmers today follow the advice of Vergil. Crop rotation, as the practice of changing crops is now called, is recognized today as very important in maintaining soil fertility.

Experiments show that different crops have different needs. Certain crops require more phosphates, others more nitrates, and still others more potash. Wheat, for example, draws heavily from the store of nitrates. Clover draws more heavily upon the potash and phosphate. By rotation of crops the drain on any particular minerals in the soil is reduced. In some cases rotation actually restores a mineral that has been seriously reduced.

The crops included in a plan of rotation are different in different places. A typical three-year plan of rotation for the farms of the Middle West is corn, wheat, and clover. In the South the rotation may consist in first cotton, then corn, and then clover or alfalfa. A four-year rotation common in New England is (1) corn, (2) oats, (3) clover, and (4) timothy. Such a crop-rotation plan is shown in the illustration on the opposite page. Notice that in all the plans mentioned above clover or alfalfa is used. The reason for this is that clover and alfalfa have the ability to store nitrogen and, when plowed under as "green manure," to give back to the soil one of its most important ingredients.

Exercise. Find a farm on which crop rotation is practiced. Ask the farmer why he practices it as he does.



Galloway

Irrigation ditches (left) bring water to fields which are too dry.
Drainage ditches (right) take water away from fields which are too wet

Other Problems of Modern Farming. As farmers have become limited in their choice of lands, and as it has become increasingly necessary for them to use what land they have, many special problems have developed. The farmer must first of all consider the crops that are adapted to his particular kind of land. If he has a warm, wet meadow south of the frost line, he may be able to raise rice. If he lives on dry wind-blown land, one of the new sorghums (plants rich in sugar and used for making molasses) may be just the thing. A farmer upon such land may be especially successful with grass and grains. Vegetables, on the other hand, should not be grown on such dry soil.

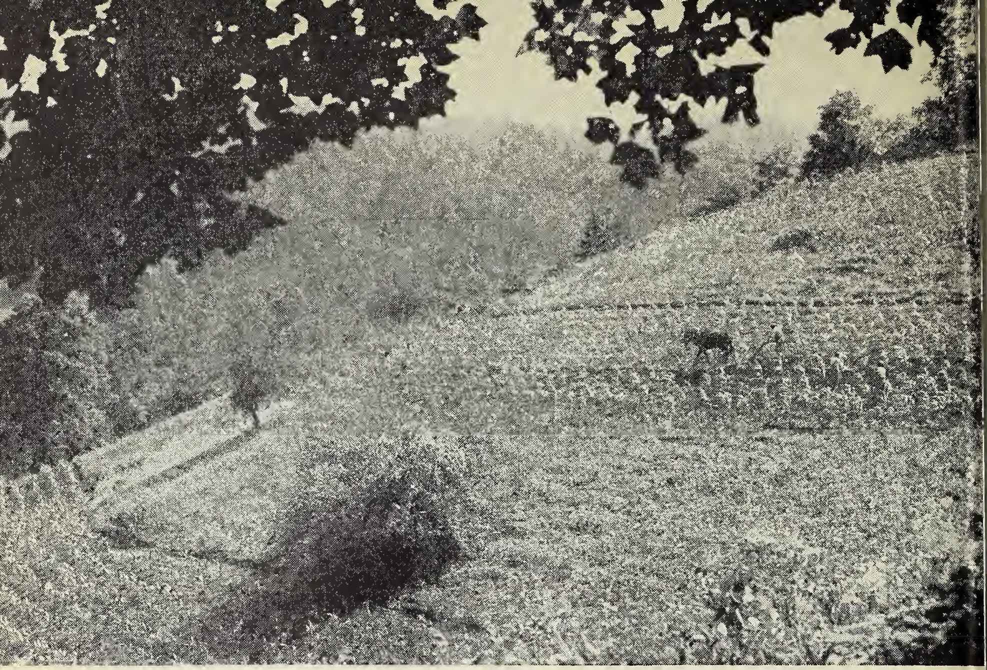
Having chosen crops as nearly suited to his land as he can find, and having taken advantage of expert advice that may be had from state college or agricultural-experiment stations, the farmer may still find it necessary either to drain his land or to irrigate it. Large areas of semidesert lands in our own West have been watered artificially by means of ditches. Other areas are crisscrossed by ditches which were dug for the purpose of draining off surplus water. The problems of too much or too little water are among the hardest to solve, and as a result there is waste land in every community.

The Problem of Preventing Erosion. Only recently have men come to realize that not only may the fertility of soils be lost but also the soils themselves. Nature makes soils very slowly from the solid rocks of the earth. In one way or another, man interferes with the balance of nature so that the soils are removed from the lands more rapidly than they are made.

We have already seen something of how the destruction of forests and grasslands makes it possible for running water and wind to carry off the soil. Bad farming practices increase the dangers of soil removal. In closing this unit let us sum up this whole great problem, which is without any doubt the major problem of conservation in the world today.

Overplowed hillsides are easy prey for running water

U. S. D. A., Soil Conservation Service



U. S. D. A., Soil Conservation Service

Horizontal (contour) plowing and planting on hilly land help to check erosion. Do you see why?

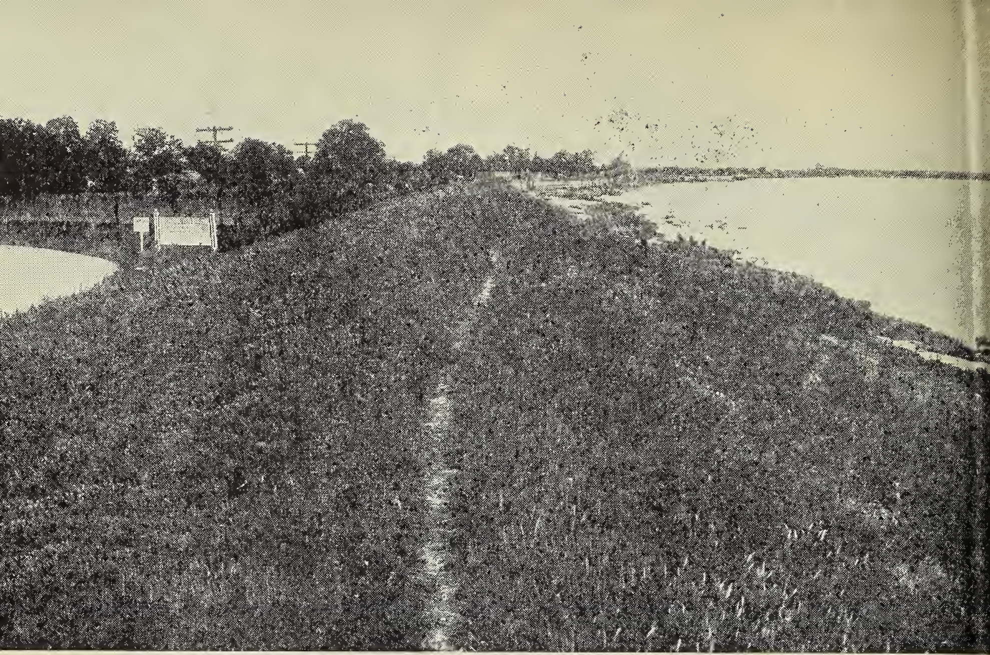
Not long ago one of the authors of this book passed a sandy hillside near a state road. A wood of white pines that had covered this area had been cut down some seven years before. Down the side of the hill gaped two ugly gullies, one about fifteen feet deep and more than thirty feet wide, the other not quite so large. At the foot of the hill and spreading well out over the cement of the state road was a **V**-shaped ridge of sand. "A few more rains," your author remarked to his companion, "and that hill will bury the road." "Bad planning, cutting those trees," the companion answered. "Trees would have held that soil. Grass would have held it. But bare soil simply cannot remain on a hillside against the force of running water."

Examples of erosion, or wearing away of the earth, can be noticed by every observing tourist almost anywhere he may go. Did you notice the color of the brook or river after the last rainstorm? Somebody's good soil gave the water that color. Somebody's good soil was on its way to the ocean—and with it somebody's means of making a living.

Experiments with erosion in Missouri have shown that rains falling on cultivated land may wash away one inch of soil in from one to seven years. It was further shown that nature takes an average of four hundred years to build up this inch of topsoil. And it may be worth while to add that topsoil, in which crops do most of their growing and from which they obtain most of their mineral food, is seldom more than six or seven inches deep. In many places it is not so deep as this. Simple arithmetic shows that *bare land may be robbed in less than a generation of the wealth which it took many hundred years to collect.*

To prevent erosion, all sloping land should be kept covered with trees or grass. Look at the hillside shown on the opposite page. Where it is absolutely necessary to use such land, terraces should be built, and grass should be left on the slopes. If grass can be grown one year in three and cultivated crops the other two years, erosion is slowed down because the grass roots remain in the soil. Alfalfa or clover may be used where necessary instead of grass, although the roots are not so thick. Gullies should be filled with straw and tree limbs while they are still small. No soil on sloping ground should be left bare at any time.

Exercise. "Contour-plowing" and "strip-cropping" are two important modern means of checking the erosion of farm lands. Look up the publications of the Soil Conservation Service, Washington, D. C. (many of which are interesting, well illustrated, and free), and find out what these methods are and how they are applied. Find out if they are being applied in your neighborhood.



Courtesy L. B. Robeson

A river confined by levees raises its elevation by dropping sediment in its own channel, and the levees must be built ever higher and higher to prevent flooding. Notice that the water at the right of the levee stands higher than the road at the left

The Problems of Flood Control. Problems of flood control are closely tied up with problems of erosion. We can find no better illustration of the connection between the two than in the case of our own Mississippi River and the area which it drains. Each year the United States government spends millions of dollars building levees to "hold the river." A levee, as shown above, is an embankment of earth piled up along a river's edge in an effort to prevent the river from overflowing upon the land.

Two centuries ago early French settlers made the first levees along the Mississippi. They were so highly successful that more people settled along the river, more people wanted their land protected, and more levees were built. In time great levees paralleled the banks of the river for two thousand miles. Having no room left to overflow in periods of flood, the river proceeded to break through the weaker spots in the levees and to destroy millions of acres of crops.

Today it is still breaking through the levees and destroying crops. Floods, indeed, are becoming worse each year. Is there more rain today? Does the river carry any more water than it did two centuries or even two generations ago? The answer is No. Water that used to trickle slowly through the northern forests and through the grass roots of the central prairies now rushes headlong to the sea. Erosion runs wild today because human stupidity and greed ran wild in the past.

Fortunately the proper solution to this problem and to all related problems of conservation is obvious, though not always easy to put into effect. We must curb the greed of the individual for the good of the people at large. We must learn to use our world without abusing it. And even in these troubled times there are signs that we actually are learning. There are signs that we Americans are learning to eat the fruit of the richest orchard of natural resources on earth without destroying the trees that produce it. Whether or not we put this learning into practice depends on you.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Modern prospecting has undoubtedly discovered all the earth's most valuable mineral deposits.

2. The only hope of metal conservation is the discovery of deposits of metal-bearing ores which are unknown at present.

3. The secondary production of iron is about one-third again as much as the primary production.

4. Plastics are too weak ever to take the place of metals to any considerable extent.

5. The problem of conserving coal and petroleum differs from the problem of conserving metals because there are no low-grade deposits of the energy minerals which can be developed when the high-grade deposits are used up.

6. With proper care, our coal and petroleum deposits can be made to last indefinitely.

7. When the present major sources of energy are used up, we shall have to depend chiefly on alcohol made from grain.

8. Any finely divided rock that contains humus is a good soil.

9. The only way of conserving the fertility of the soil is to let farm lands lie idle every other year.

10. The problem of restoring soluble minerals to the soil of farms is the only serious problem of the modern farmer.

11. It takes nature from one to seven years to make one inch of soil.

12. Levees are the only effective way of controlling floods.

Questions for Discussion

1. What influence do you believe mineral resources have on war? Do you believe that if all countries had equal shares of the world's metal and fuel supplies there would ever be war?

2. Do you believe, as some agricultural experts do, that some lands in the United States are so poor that they are not worth farming? If so, to what use do you think these lands should be put?

3. Do you believe that conservation measures are needed in the vicinity of your home? If so, what measures and why?

Things to Do

1. Keep a conservation scrapbook. Items are continually appearing in the magazines and newspapers on various types of conservation. You might arrange your scrapbook under the following headings: Forests, Grasslands, Wild Life, Metals, Fuels, Soils.

2. The Soil Conservation Service has many erosion-control demonstration areas in the United States. Find out where the one nearest your home is located, and arrange for your class to visit it.

3. Look up and make a report on the worst floods in America during recent times. See if you can determine the cause of these floods and what conservation measures might prevent similar ones in the future.

4. Read *To Hold This Soil,* by Russell Lord, published by the United States Department of Agriculture. It is one of the most interesting explanations of the erosion problem ever written.

Readings in Science

ANDRESS, J. MACE, GOLDBERGER, I. H., and HALLOCK, GRACE T. *Helping the Body in Its Work.* Ginn and Company, Boston, 1939.

A straightforward, simple physiology for older boys and girls, with an entire unit devoted to safety.

ANDREWS, ROY C. *Exploring with Andrews.* G. P. Putnam's Sons, New York, 1938.

A book for younger readers, describing adventures in the life of this famous explorer.

BAER, MARIAN. *Pandora's Box.* Farrar & Rinehart, Inc., New York, 1939.

A story of conservation of our natural resources.

BEEBE, WILLIAM. *Pheasants: Their Lives and Homes.* Doubleday, Doran & Company, Inc., New York, 1931.

Two beautifully illustrated volumes describing jungle fowl and other pheasants in their natural habitats.

BLACK, ARCHIBALD. *The Story of Bridges.* McGraw-Hill Book Company, Inc., New York, 1936.

A history of bridges and their construction, from ancient to modern times.

BOCK, GEORGE E. *What Makes the Wheels Go Round?* The Macmillan Company, New York, 1931.

The author explains simply, clearly, and by means of excellent diagrams how simple machines work, how steam and power plants work, and how the gasoline motor works.

BORTH, CHRISTY. *Pioneers of Plenty.* Bobbs-Merrill Company, Indianapolis, 1939.

A description of the new discoveries and products in chemistry on the farm and in the forest.

BRADLEY, JOHN H., JR. *Autobiography of Earth.* Coward-McCann, Inc., New York, 1935.

A story of the earth's beginnings and of rocks, volcanoes, rivers, and minerals today. Man is the central figure.

Buchsbaum, Ralph. *Animals without Backbones.* University of Chicago Press, 1938.

Some of these little animals have serious effects on our health. The book is easy to read, and the illustrations are unusual.

Byrd, Richard E. *Discovery.* G. P. Putnam's Sons, New York, 1935.

The story of the second Byrd antarctic expedition.

Chase, Carl T. *Frontiers of Science.* D. Van Nostrand Company, Inc., New York, 1936.

Describing some of the newer discoveries in science and their probable effects on human destiny.

Chase, Stuart. *Rich Land, Poor Land.* McGraw-Hill Book Company, Inc., New York, 1936.

A story of the natural resources of the United States, their use and misuse.

Coburn, Walter E. *High School Electricity Manual.* John Wiley & Sons, Inc., New York, 1932.

This text on electricity for industrial arts courses is a good work of reference and gives many experiments.

Collins, A. Frederick. *Experimental Mechanics.* D. Appleton-Century Company, Inc., New York, 1931.

Various models, levers, linkages, wheels, gears, shafts, movements, and mechanisms are explained, many of which one might easily construct.

Collins, A. Frederick. *Experimental Optics.* D. Appleton-Century Company, Inc., New York, 1933.

An unusually good collection of experiments, most of which are not difficult to perform.

Collins, A. Frederick. *Fun with Electricity.* D. Appleton-Century Company, Inc., New York, 1936.

A book of tricks and experiments illustrating some important ideas in the area of energy transformations.

Collins, A. Frederick. *The Metals.* D. Appleton-Century Company, Inc., New York, 1932.

This book deals with the various alloys, amalgams, and compounds of the different metals.

Crowther, J. G. *Men of Science.* W. W. Norton & Company, Inc., New York, 1936.

A series of biographies of outstanding leaders in various fields of science.

Curie, Eve. *Madame Curie.* Doubleday, Doran & Company, Inc., New York, 1938.

This inspiring biography of the woman who discovered radium, by her daughter, should be one of the long-remembered books of our time.

de Kruif, Paul. *Hunger Fighters.* Harcourt, Brace and Company, New York, 1928.

A well-known and well-written book on the control of plants and animals that we use as food.

de Kruif, Paul. *Men against Death.* Harcourt, Brace and Company, New York, 1932.

This book, like *Microbe Hunters,* consists of biographical sketches telling about recent scientific discoveries that doctors are making in the fight against disease.

de Kruif, Paul. *Microbe Hunters.* Harcourt, Brace and Company, New York, 1926.

Stories of the lives of many of the leading scientists in the discovery and control of microbes.

Ditmars, Raymond Lee. *The Fight to Live.* Frederick A. Stokes Company, New York, 1938.

Defensive mechanisms of birds, reptiles, and mammals used for protection against enemies, in the search for food and in defense of their young.

Ditmars, Raymond Lee. *Snakes of the World.* The Macmillan Company, New York, 1931.

This gives interesting descriptions of snakes and their habits, together with eighty-four remarkable full-page photographs of them. An important book for anyone who wishes to know the real place of snakes in the balance of nature.

Eaton, Jeannette. *The Story of Light.* Harper & Brothers, New York, 1937.

From the discovery of fire to the modern incandescent lamp. Well written and interesting.

Eaton, Jeannette. *The Story of Transportation.* Harper & Brothers, New York, 1937.

From Indian trails through sailing boats, trains, and steamboats to the airplane.

EMERSON, CAROLINE D. *Father's Big Improvements.* Frederick A. Stokes Company, New York, 1936.

"Water did not always run in pipes, and wires did not always carry messages." Many changes have taken place in one lifetime because of scientific progress. This little book tells about some of them.

FISK, DOROTHY M. *Modern Alchemy.* D. Appleton-Century Company, Inc., New York, 1936.

A simply written description of the newer discoveries in physics.

FLINT, W. P., and METCALF, C. L. *Insects: Man's Chief Competitors.* The Williams & Wilkins Company, Baltimore, 1932.

This is an exposition of the struggle between man and insects for top place in the balance of nature.

FLOHERTY, JOHN J. *On the Air: The Story of Radio.* Doubleday, Doran & Company, Inc., New York, 1937.

A little book on the principles of radio broadcasting.

FLOHERTY, JOHN J. *Youth at the Wheel.* J. B. Lippincott Company, Philadelphia, 1937.

Lessons in automobile safety through better understanding of the principles of driving.

FRANCIS, MARGARET FOX. *Flowers and Their Travels.* Bobbs-Merrill Company, Indianapolis, 1936.

Where our plants come from, and how they got here.

FURNAS, C. C. *The Next Hundred Years.* Reynal & Hitchcock, Inc., New York, 1936.

"The unfinished business of science," with descriptions of what has already been accomplished.

FURNAS, C. C. *Storehouse of Civilization.* Teachers College, Columbia University, New York, 1939.

Excellent illustrations in a book telling the story of tree conservation by the United States Forest Service, with emphasis on its relations to soil and water conservation.

GLOVER, KATHERINE. *America Begins Again.* McGraw-Hill Book Company, Inc., New York, 1939.

The story of how America has at last begun to conserve its natural resources.

GRIMES, W. E., and HOLTON, E. L. *Modern Agriculture.* Ginn and Company, Boston, 1931.

A good reference for the first unit.

GUSTAFSON, A. F., RIES, H., GUISE, C. H., and HAMILTON, W. J., JR. *Conservation in the United States.* Comstock Publishing Company, Inc., Ithaca, New York, 1939.

Excellent for reference on all phases of conservation: soil, water, forests, wild life, and minerals.

HAGGARD, HOWARD W. *Devils, Drugs, and Doctors.* Blue Ribbon Books, Inc., New York, 1933.

Interesting and readable history of healing from medicine man to modern doctor.

HALL, CHARLES GILBERT. *Skyways.* The Macmillan Company, New York, 1938.

An up-to-the-minute history of aviation, with many illustrations.

HODGINS, E., and MAGOUN, F. A. *Sky High.* Little, Brown and Company, Boston, 1937.

A history of aviation from the fourth century B.C. until today.

HOUSE, HOMER D. *Wild Flowers.* The Macmillan Company, New York, 1934.

Color plates, in natural size, of the common wild flowers of New York and other northeastern states.

HUXLEY, JULIAN SORELL. *Science and Social Needs.* Harper & Brothers, New York, 1935.

Discusses the economic and social effects of scientific achievements.

ILIN, MAX. *Turning Night into Day.* J. B. Lippincott Company, Philadelphia, 1936.

The story of lighting, by a Russian author, written for use in Russian schools.

JAFFE, BERNARD. *Outposts of Science.* Simon and Schuster, Inc., New York, 1935.

A journey to the workshops of our leading men and women of research.

JEANS, SIR JAMES H. *Through Space and Time.* The Macmillan Company, New York, 1934.

This book gives an understanding of space and time as gained through study of geology and astronomy.

KALLET, ARTHUR, and SCHLINK, F. J. *100,000,000 Guinea Pigs.* Vanguard Press, Inc., New York, 1932.

There are dangers in some commonly used foods, drugs, and cosmetics. Others are entirely useless.

Lamb, Frank H. *Book of the Broadleaf Trees.* W. W. Norton & Company, Inc., 1939.

How the broad-leaved trees of the temperate zone contribute to economic and social welfare.

Leonard, Jonathan Norton. *Tools of Tomorrow.* Viking Press, Inc., New York, 1935.

How machines and energy control are giving us new means for better living. Many gifts of applied science are available to us as soon as we have learned to use them.

Loomis, F. B. *Field Book of Common Rocks and Minerals.* G. P. Putnam's Sons, New York, 1923.

A handbook for the identification of rocks and minerals, with good illustrations and careful descriptions.

Lord, Russell. *Forest Outings.* United States Department of Agriculture, 1940.

A handsomely illustrated and interesting book on how we can best use and enjoy our national forests.

Lorentz, Pare. *The River.* Stackpole Sons, New York, 1938.

A description, with many pictures, of the effects of rivers on human living. The story is the script of the United States documentary film of the same title.

Luckiesh, Matthew. *Seeing and Human Welfare.* The Williams & Wilkins Company, Baltimore, 1934.

This authority on light reveals how to maintain the best conditions for eyes, and indicates the demands made upon them.

Lutz, F. *Field Book of Insects.* G. P. Putnam's Sons, New York, 1921.

The book you need if you have found an insect that you cannot identify.

Mason, Gregory. *Columbus Came Late.* D. Appleton-Century Company, Inc., New York, 1931.

An account of ancient American civilizations—Maya, Toltec, Aztec—in Mexico. There are descriptions of Indian food plants and of the progress of these people in mathematics, astronomy, and agriculture.

Meriwether, Susan. *The Story of the Telephone.* Harper & Brothers, New York, 1937.

The history of communication, leading up to the modern telephone.

MEYER, BERL BEN. *Your Germs and Mine.* Doubleday, Doran & Company, Inc., New York, 1934.

About beneficial and harmful microbes, immunity and resistance.

MORGAN, ALFRED. *Getting Acquainted with Radio.* D. Appleton-Century Company, Inc., New York, 1940.

A really readable description of the workings of receivers and transmitters and of the theory of radio.

MORGAN, ALFRED. *Things a Boy Can Do with Electricity.* Charles Scribner's Sons, New York, 1938.

An excellent book to acquaint the student with electricity.

MOSELEY, S. A., and MCRAY, H. *Television: A Guide for the Amateur.* Oxford University Press, New York, 1936.

This book makes easy a timely but difficult phase of present-day entertainment and communication.

MOTT-SMITH, MORTON. *This Mechanical World: An Introduction to Popular Physics.* D. Appleton-Century Company, Inc., New York, 1931.

Gives a knowledge of mechanics which will serve as a basis for the appreciation of what is being written and done in science.

MUENSCHER, WALTER C. *Weeds.* The Macmillan Company, New York, 1935.

A book for reference, with descriptions and a botanical key, so that you may know weeds and what to do about them. Many of them you may identify from the pictures.

MULLER, CHARLES G. *How They Carried the Goods.* Dodd, Mead & Company, New York, 1932.

Transportation from the days of the Pharaohs to the days of modern airplanes.

NEILL, HUMPHREY B. *Forty-eight Million Horses.* J. B. Lippincott Company, Philadelphia, 1940.

"Electricity is the hero of this tale." "This is a book of journeys to the sources and users of electrical energy." The quotations are two sentences from the first page of the foreword.

NICOLAY, HELEN. *Wizard of the Wires.* D. Appleton-Century Company, Inc., New York, 1938.

Biography of Samuel Morse and the story of telegraphy.

PARKINS, A. E., and WHITAKER, J. R. *Our Natural Resources and Their Conservation.* John Wiley & Sons, Inc., New York, 1936.

A detailed authoritative study of our natural resources, for adult use.

PATCH, EDITH M. *Holiday Hill.* The Macmillan Company, New York, 1935.

A simple but accurate little book with much information about rocks and soils.

PEAKE, HAROLD J. *Early Steps in Human Progress.* J. B. Lippincott Company, Philadelphia, 1933.

Man's progress during the many years of the Stone Age, with descriptions of his many inventions and discoveries.

PEARSON, T. GILBERT. *Birds of America.* Garden City Publishing Company, Inc., New York, 1936.

Many pictures, some in color, with descriptions of all the common birds of the United States.

PEATTIE, DONALD C. *Green Laurels.* Simon and Schuster, Inc., New York, 1936.

Story of the discovery of the living world, through the biographies of the men who have led in the discovery.

PEATTIE, DONALD C. *Audubon's America.* Houghton Mifflin Company, Boston, 1940.

The writings and paintings of a great early American naturalist, ably edited and handsomely printed.

POPE, CLIFFORD H. *Snakes Alive.* Viking Press, Inc., New York, 1937.

How snakes live, with an illustrated key for identifying the snakes of the United States.

READ, THOMAS T. *Our Mineral Civilization.* The Williams & Wilkins Company, Baltimore, 1932.

A little book describing progress and changes in the use of minerals during the last hundred years.

REED, W. MAXWELL. *America's Treasure.* Harcourt, Brace and Company, New York, 1939.

Good chapters on copper, iron, aluminum, fuels, building stones, and the protection of these resources. Easy reading.

REED, W. MAXWELL. *And That's Why.* Harcourt, Brace and Company, New York, 1935.

Simple explanations of such facts as why the ocean is salty, where to find petroleum, why mists hang over valleys in the evening, and the like.

ROGERS, FRANCES, and BEARD, ALICE. *Five Thousand Years of Glass.* Frederick A. Stokes Company, New York, 1937.

The science of glassmaking, our first plastic, from ancient times to the present.

ROSS, M. I. *Back of Time.* Harper & Brothers, New York, 1937.

Describing a scientific expedition in search of information about plants and animals in prehistoric deposits.

ROULE, LOUIS. *Fishes, Their Journeys and Migrations.* George J. McLeod, Ltd., Toronto, 1933.

Telling the life stories of many of the fish that migrate, including the salmon, trout, and eel.

SAUNDERS, CHARLES F. *Useful Wild Plants of the United States and Canada.* Robert M. McBride & Company, New York, 1934.

Even today many agricultural conquests remain to be made.

SEARS, PAUL B. *Deserts on the March.* University of Oklahoma Press, 1935.

When good soil becomes desert because of man's ill treatment of it, the history of a country may become the history of a desert on the march.

SNYDER, THOMAS ELLIOTT. *Our Enemy the Termite.* Comstock Publishing Company, Inc., Ithaca, New York, 1935.

A vivid description of an insect that may do much damage to houses when man disturbs the balance of nature.

STANFORD, ERNEST E. *Economic Plants.* D. Appleton-Century Company, Inc., New York, 1934.

A rather complete treatment, describing most of the economic plants and their products. Good for reference.

STARRETT, PAUL. *Changing the Skyline.* McGraw-Hill Book Company, Inc., New York, 1938.

A biography of the Starrett brothers in terms of the construction of such skyscrapers as the Empire State Building.

STEFANSSON, VILHJALMUR. *Friendly Arctic.* The Macmillan Company, New York, 1921.

A classic in showing that the arctic regions have much to offer in the way of resources and possibilities for happy living.

TEALE, EDWIN W. *The Boy's Book of Insects.* E. P. Dutton & Company, Inc., New York, 1939.

A beautifully illustrated book about common insects, with photographs by the author.

TEALE, EDWIN W. *Grassroot Jungles.* Dodd, Mead & Company, New York, 1937.

Excellent photographs and descriptions of the common creatures in the grass "jungles" under our feet.

THOMAS, LOWELL. *Magic Dials.* Lee Furman, Inc., New York, 1939.

The story of radio and television, simply told, with many illustrations.

THOMSON, J. ARTHUR. *The Outline of Science.* G. P. Putnam's Sons, New York, 1937.

The story of the triumphs of modern science in all its different branches.

VAN LOON, HENDRIK. *The Story of Mankind.* Garden City Publishing Company, Inc., New York, 1926.

A simple and interesting study of the lives and customs of our earliest human ancestors and others not so ancient.

WELLS, H. G. *Outline of History.* The Macmillan Company, New York, 1921.

Includes much science throughout the ages.

WELLS, H. G., HUXLEY, JULIAN S., and WELLS, G. P. *The Science of Life.* Doubleday, Doran & Company, Inc., New York, 1931.

A compilation of biological knowledge into which some abler students may wish to delve.

WILDER, LOUISE B. *The Garden in Color.* The Macmillan Company, New York, 1937.

Over three hundred natural-color and natural-size plates of garden flowers from early spring to late autumn.

WILHELM, DONALD GEORGE. *The Book of Metals.* Harper & Brothers, New York, 1932.

Characteristics, history, mining, refining, alloying, and uses of metals.

WILHELM, DONALD GEORGE. *The Story of Iron and Steel.* Harper & Brothers, New York, 1937.

The story of two metals of first importance to civilization from primitive days to modern methods of refining.

WOODBURY, DAVID. *The Glass Giant of Palomar.* Dodd, Mead & Company, New York, 1939.

A story of the making of the new telescope for Mt. Palomar, with emphasis on the scientific problems involved.

ZINSSER, HANS. *Rats, Lice, and History.* Little, Brown, and Company, Boston, 1935.

The part played by certain parasites in spreading disease.

Science Words

KEY TO THE SOUNDS

ă *as in* at
ā *as in* ate
â *as in* care
ȧ *as in* ask
ä *as in* arm
a̯ *as in* sofa
ĕ *as in* bet
ē *as in* be
ẽ *as in* her
e̯ *as in* vowel
ĭ *as in* bit
ī *as in* bite
ŏ *as in* got
ō *as in* go
ô *as in* horse
o̯ *as in* connect
oi *as in* oil
o͞o *as in* food
o͝o *as in* foot
ŭ *as in* us
ū *as in* use
u̯ *as in* circus
û *as in* urn
t͜ū *as in* nature
ŋ *as in* ink

Aberdeen Angus (ăb′ẽr dēn ăng′gu̯s). A breed of black, hornless beef cattle (p. 53)[1]

abrasive (ăb rā′sĭv). A substance used for grinding or polishing (p. 170)

activated sludge (ăk tĭ vā′tĕd slŭj) *main.* A pipe for removing the mudlike substance obtained by treating sewage (p. 486)

adrenal (ăd rē′na̯l). Located near the kidneys. Adrenal glands (p. 421)

aeration (ā ẽr ā′shu̯n) *tank.* A tank in which sewage is exposed to air (p. 486)

Aesculapius (ĕs kū lā′pĭ u̯s). The Greek and Roman god of medicine and healing (p. 441)

alkaline (ăl′ka̯ līn). Having the properties of an alkali; a substance able to neutralize acids (p. 76)

alloy (ă loi′). A substance composed of two or more metals (p. 113)

alternating (ôl′tẽr nāt ĭng) *current.* A current of electricity in which the direction of the flow changes at regular intervals, usually many times per second (p. 322)

amber (ăm′bẽr). A fossil resin which is yellow to brown in color. It is hard and brittle and takes a fine polish (p. 307)

ammonia (ă mō′nĭ a̯). A colorless gas composed of nitrogen and hydrogen. Ordinary ammonia is a solution of this gas in water (p. 188)

ammonium chloride (ă mō′nĭ u̯m klō′rīd). A white compound of nitrogen, hydrogen, and chlorine. When powdered, it is used for filling dry cells (p. 152)

[1] References are to pages in the text where the words first occurred.

ammonium sulfate (ă mō′nĭ ṷm sŭl′fāt). A compound used in the manufacture of fertilizers (p. 77)

Ampère (äŋ pâr′), *André* (1775–1836). French scientist and author (p. 329)

ampere (ăm′pēr). A measure of the quantity of electricity flowing past a point in one second (p. 329)

anemia (a̭ nē′mĭ a̭). A deficiency of the red corpuscles in the blood (p. 423)

Angus (p. 52). See *Aberdeen Angus*

animal husbandry (hŭz′ba̭nd rĭ). The breeding and care of farm animals (p. 59)

anneal (ă nēl′). To temper glass or metals by heating, then cooling; this process thoroughly softens the material and makes it less brittle (p. 180)

anther (ăn′thẽr). The part of the stamen of a flower which contains the pollen (p. 27)

anthracite (ăn′thra̭ sīt). A hard coal, which yields comparatively little gas when heated (p. 196)

antitoxin (ăn tĭ tŏk′sĭn). A substance formed in a living thing which will overcome the effects of a toxin (p. 449)

aorta (ā ôr′ta̭). The large artery carrying blood from the left side of the heart to the other arteries which distribute it through the body (p. 419)

Archimedes (är kĭ mē′dēz) (287?–212 B.C.). A Greek scientist and mathematician, known to us especially for his law of buoyancy and his work with simple machines (p. 230)

argon (är′gŏn). A gaseous element occurring in small amounts in the air (p. 301)

armature (är′ma̭ tū̮r). A piece of soft iron or steel used to connect two magnetic poles (p. 320). The movable part of a dynamo or motor, consisting of coils of wire around an iron core (p. 325)

arsenic (är′sĕ nĭk). One of the elements; it is solid, brittle, and grayish-black (p. 148)

artery (är′tẽr ĭ). Any of the tubes which carry blood away from the heart (p. 413)

artifact (är′tĭ făkt). Anything made by man, especially by primitive man (p. 107)

asbestos (ăs bĕs′tṷs). A kind of mineral not affected by fire (p. 191)

assay (a̭ sā′). To analyze; to determine the amount of metal in an ore (p. 555)

atom (ăt′ṷm). A small particle, or bit, of substance composed of an equal number of protons and electrons (p. 312) *auditory* (ô'dĭ tō rĭ) *nerve.* The nerve which connects the brain and the ear (p. 428)

Audubon (ô'do͝o bŏn), *John James* (1780–1851). An American artist and naturalist, who studied and painted birds (p. 539)

auger (ô'gẽr). A tool for boring holes (p. 244)

auricle (ô'rĭ k'l). One of the two upper chambers of the heart (p. 419)

autonomic (ô tō nŏm'ĭk) *nervous system.* A system of nerve tissues which controls such inner organs as the stomach and the intestines (p. 425)

axis (ăk'sĭs). A straight line upon which a body turns (p. 391)

Ayrshire (âr'shĭr). A hardy breed of dairy cattle (p. 53)

Aztec (ăz'tĕk). An Indian tribe of southwestern North America (p. 13)

bacteria (băk tēr'ĭ a̯) (singular *bacterium* [băk tēr'ĭ u̯m]). Plants so small that they can be seen only through a microscope. Many bacteria cause diseases, but many others are very useful to man (p. 96)

bakelite (bā'ke̯ līt). An artificial substance with uses similar to those of hard rubber (p. 560)

balance of nature. The condition in nature in which the smaller and weaker animals are more abundant than the larger and stronger animals, and thus are able to survive (p. 496)

ballast (băl'a̯st) *tank.* A tank containing more or less water to vary the weight of a submarine (p. 374)

barite (bâr'īt). A mineral often present in metal deposits; it is used in some plants (p. 191)

bauxite (bō'zīt). A mineral, like clay, from which aluminum may be obtained (p. 155)

Bessemer (bĕs'e̯ mẽr) *process.* A process of making steel from pig iron by burning out impurities (p. 140)

binding post. The part of any electrical apparatus to which connecting wires may be attached (p. 127)

bituminous (bĭ tū'mĭ nu̯s). Soft coal; when heated it gives off a large amount of gas (p. 196)

blackleg (blăk'lĕg). A disease of young cattle; it is usually fatal (p. 96)

blast furnace. A furnace in which burning is forced by a blast of hot dry air (p. 115)

blended inheritance. Inheritance in which the first-generation offspring show a mixture of the traits of the parents (p. 30)

blight (blīt). A disease of plants causing withering (p. 95)

block and tackle. An arrangement of pulleys and ropes (p. 235)

boomerang (bo͞om'ẽr ăng). A curved club which, when thrown, returns to a spot near that from which it was thrown (p. 104) *borax* (bō′răks). A mineral, a compound of sodium, used in cleansing and disinfecting (p. 191)

Boulder Dam. A dam on the Colorado River designed for flood control, irrigation, and power production (p. 174)

Bronze Age. A period in the history of man's development, which takes its name from the widespread use of bronze (p. 106)

bubonic plague (bū bŏn′ĭk plāg). An epidemic disease which is marked by fevers, chills, and the swelling of certain glands (p. 483)

budding. A process in which a bud of one plant is placed in a slit in the bark of another plant (p. 23)

buoyancy (bo͞o′yạn sĭ). The upward push of a liquid or a gas on an object in it (p. 372)

Burbank (bûr′băngk), *Luther* (1849–1926). An American naturalist who developed many new fruits and flowers (p. 34)

Bureau of Biological Survey. A bureau in the United States Department of Agriculture (p. 544)

Bureau of Fisheries. A division of the United States Department of Commerce (p. 544)

butterfat (bŭt′ẽr făt). The natural fat of milk (p. 53)

calcium (kăl′sĭ ụm). A silver-white soft metal, whose compounds occur in nature (p. 118)

calcium carbonate (kär′bŏn āt). A compound of calcium, carbon, oxygen; marble and limestone are forms of calcium carbonate (p. 120)

calcium oxide (ŏk′sīd). A compound of calcium and oxygen (p. 173)

calcium phosphate (fŏs′fāt). A compound of calcium, phosphorus, and oxygen, important in bone formation (p. 410)

camera obscura (kăm′ẽr ạ ŏb skū′rạ). A darkened box or closet having a small opening through which light enters. An image is formed on the surface opposite (p. 305)

capstan (kăp′stạn). A device for moving heavy weights, used especially on shipboard (p. 239)

carbohydrate (kär bō hī′drāt). Food that is a compound of carbon, hydrogen, and oxygen. Sugars and starches are examples of carbohydrates (p. 62)

carbolic (kär bŏl′ĭk) *acid.* A disinfectant (p. 76)

carbon (kär′bọn). An element which is contained in all living materials. Charcoal, coal, and graphite are forms of carbon (p. 118)

carbon dioxide (kär′bọn dī ŏk′sīd). One of the gases in the air. It is a nonpoisonous product of respiration and of burning, and is needed by plants for food-making (p. 140)

carbon monoxide (mŏn ŏk′sīd). A poisonous gas which is both colorless and odorless. It is formed when there is not enough oxygen present for carbon to burn completely (p. 140)

carbon tetrachloride (tĕt ra̯ klō'rīd). A colorless liquid compound of carbon and chlorine. It will not burn (p. 520)

carburetor (kär'bū rĕt ẽr). A mechanism in an automobile or other gas engine which mixes gasoline vapor with air (p. 271)

caribou (kăr'ĭ bo͞o). A kind of reindeer of northern America and Greenland (p. 535)

casing pipe. A pipe that is fitted around a drill pipe in order to protect it (p. 207)

cell. A means by which chemical energy can be changed to electric energy (p. 128). The smallest complete unit or part of living matter (p. 419)

cellophane (sĕl'ō fān). Thin, transparent, waterproof sheets of a material manufactured from cellulose (p. 524)

cellulose (sĕl'ū lōs). The solid framework of plants, the woody parts, used for making rayon and many other substances (p. 524)

centaur (sĕn'tôr). An imaginary being, part man and part horse (p. 441)

cerebellum (sĕr ĕ bĕl'u̯m). The part of the brain next to the spinal cord (p. 434)

cerebrospinal (sĕr'ĕ brō spī'na̯l) *nervous system.* The system of nerve tissues which includes the brain, the spinal cord, and related nerves (p. 425)

cerebrum (sĕr'ĕ bru̯m). The upper portion of the brain (p. 434)

charge (chärj). Literally, a burden. An object has an electric charge when its electrons and protons are not equal in number (p. 308)

chaulmoogra (chôl mo͞o'gra̯) *oil.* The oil of an East Indian tree, used in medicine (p. 458)

chemical (kĕm'ĭ ka̯l). Relating to chemistry, that branch of science which deals with the changing of one substance into another (p. 117)

chinch (chĭnch) *bug.* An insect very destructive to grains, especially in dry seasons (p. 79)

chlorine (klō'rēn). A heavy, greenish-yellow poisonous gas with a suffocating odor (p. 120)

chlorophyll (klō'rō fĭl). The green coloring matter of plants (p. 89)

cholera (kŏl'ẽr a̯). Any one of a number of similar diseases of man or animals (p. 96)

chromium (krō'mĭ u̯m). A hard metal that does not rust readily. It is used to make alloys and to coat other metals (p. 118)

cinchona (sĭn kō'na̯). A tree of South America and the Indies; from its bark quinine is obtained (p. 18) *circuit* (sûr'kĭt). The complete path of an electric current (p. 321)

Civilian Conservation Corps. A government agency which provides training and employment for young men in connection with conserving and developing our natural resources (p. 517)

coal gas. Gas made by heating bituminous coal (p. 201)

coke (kōk). The substance left after coal has been heated and the gas driven off (p. 139)

Colorado potato beetle. A beetle which feeds on the leaves of potato vines both in the adult stage and in the larval stage (p. 79)

combustion (kŏm bŭs'chu̯n). Burning; uniting with oxygen when heat and light are given off (p. 254)

compost (kŏm'pōst). Decaying material used as fertilizer (p. 569)

compound (kŏm'pound). A substance which is formed from at least two elements and which has different properties from either of them (p. 112)

compound bar. A metal bar made of strips of different metals riveted together (p. 262)

compression (kŏm prĕsh'u̯n) *stroke.* The second stroke of the piston in a gasoline engine. It squeezes the fuel into a very small space (p. 272)

concave (kŏn'kāv). A mirror or a lens which is thicker at the edges than in the center (p. 296)

Concord (kŏn'kôrd) *grape.* The leading American variety of grape. It has large, bluish-black, sweet fruit (p. 24)

conduction (ko̯n dŭk'shu̯n). The transfer of heat through a substance. When one end of a piece of metal is held in a flame, for instance, the other end becomes hot because of the conduction of heat (p. 254)

conductor (ko̯n dŭk'tẽr). A substance that will allow heat or electricity to travel through it; most metals are good conductors (p. 145)

conservation (kŏn sẽr vā'shu̯n). The protection of our natural wealth from loss or injury (p. 491)

contour (kŏn'to͝or) *plowing.* Plowing in which the furrows curve around slopes, instead of going up and down hill (p. 574)

convection (ko̯n vĕk'shu̯n). The transfer of heat in gases, such as air, and in liquids, such as water, by means of moving currents (p. 254)

convex lens. A lens thicker in the center than at the edges (p. 289)

conveyor (ko̯n vā'ẽr) *belt.* An endless belt of canvas, leather, or metal operating over pulleys or rollers (p. 200)

copper sulfate (kŏp'ẽr sŭl'fāt). A poisonous copper compound, often called blue vitriol (p. 149)

cornea (kôr'nē a̯). The transparent part of the coat of the eyeball. It covers the iris and the pupil (p. 294) *corpuscle* (kôr′pŭs′l). A small cell floating in the blood or lymph of the body (p. 419)

cortex (kôr′tĕks). The outer layer of the gray matter of the brain (p. 434)

cotton-boll weevil. A small beetle which does much damage to the cotton plant (p. 79)

crack. To heat petroleum under pressure so that the oil is broken up into simpler substances (p. 210).

creosote (krē′ō sōt). An oily, tarlike liquid (p. 87)

Cro-Magnon (krō′mȧ nyôŋ′) *man.* One of the early races of man. Cro-Magnon man was tall and erect and was more advanced than Neanderthal man (p. 108)

crop rotation. Planting crops in such an order that those which remove minerals from the soil are followed by those which give minerals back to the soil (p. 570)

crossbreeding. The crossing, or mating, of two varieties in order to produce a different type of individual (p. 24)

cross-fertilization. The fertilization of an egg cell from one plant with a sperm cell of another plant (p. 25)

cross-pollination (krŏs pŏl ĭ nā′shṷn). The transfer of pollen from the stamen of one flower to the pistil of another (p. 27)

crude oil. Petroleum as it is removed from the earth, before it has been purified (p. 210)

crust of the earth. The outer portion of the earth, the part on which we live and which we can study by observation (p. 118)

culture (kŭl′t͜ūr). The stage of civilization in which a group of people lives (p. 104)

cutting. A small piece of a plant, as a short stem, which, when placed in soil and carefully grown, will form a new plant (p. 16)

cycle (sī′k′l). A complete course of operations, returning to the original state (p. 358)

cylinder (sĭl′ĭn dẽr). Part of a steam or gas engine (p. 116)

Date Line, International. An imaginary line fixed by international agreement as the place where each calendar day first begins (p. 396)

daylight-saving time. Clock time which is one hour ahead of standard time (p. 402)

density (dĕn′sĭ tĭ). The quantity of anything per unit volume (p. 156)

diaphragm (dī′a̭ frăm). A disk or membrane free to move forward and backward, as in a telephone transmitter (p. 349). The layer of muscle tissue dividing the chest cavity from the abdomen (p. 413)

Diesel, Rudolph (1858–1913). A German inventor (p. 275)

Diesel (dē′zḙl) *engine.* A form of internal combustion engine in which the explosion takes place at high temperatures and pressures without the action of a spark (p. 274)

diffuse (dĭ fūz′). To spread about; to scatter widely (p. 287)

digitalis (dĭj ĭ tā′lĭs). The seeds or leaves of the foxglove, used in medicine (p. 72)

diphtheria (dĭf thēr′ĭ a̭). A disease caused by bacteria which live in the throat and produce a poison which enters the blood (p. 445)

direct current. A current of electricity in which the direction of the flow remains the same (p. 322)

Division of Range Research. One of the Forest Research divisions of the United States Department of Agriculture Forest Service (p. 534)

dock (dŏk). A kind of weed, having long roots (p. 19)

dogbane (dŏg′bān). A plant whose milky juice is poisonous (p. 71)

dominant (dŏm′ĭ na̭nt). Characteristics which appear in the first generation of hybrids are said to be dominant (p. 30)

drill pipe. A part of the apparatus used in drilling for oil (p. 207)

duralumin (dū răl′ū mĭn). A strong, hard, light alloy of copper, magnesium, manganese, and aluminum (p. 130)

Dutch elm disease. A disease of the elm tree; it causes the leaves to turn yellow and drop off and the tree to die (p. 93)

dynamo (dī′na̭ mō). A machine for producing electric energy from mechanical energy (p. 325)

Edison, Thomas A. (1847–1931). A very well-known American electrician and inventor (p. 356)

egg cell. A female cell, which, when fertilized by a sperm cell, may develop into a new organism (p. 25)

electrolysis (ē lĕk trŏl′ĭ sĭs). The process of breaking down, or decomposing, a substance by the use of an electric current (p. 148)

electromagnet (ē lĕk trō măg′nĕt). A piece of soft iron surrounded by a coil of wire through which an electric current is passed (p. 319)

electromagnetic induction (ē lĕk trō măg nĕt′ĭk ĭn dŭk′shṷn). The process by which a current is set up in a circuit when it is moved in a magnetic field or when the magnetic field is moved or varied in strength (p. 324)

electron (ē lĕk′trŏn). A particle of negative electricity (p. 312)

electroplating (ē lĕk′trō plāt′ĭng). The process of plating by electricity, as plating with silver or copper (p. 149)

element (ĕl′ē mĕnt). A substance composed of only one kind of material. There are ninety-two known elements, which combine to make all the other substances that we know (p. 68) *elm-bark beetle.* A beetle introduced from Europe, which injures the bark of elm trees (p. 93)

energy (ĕn′ẽr jĭ). The ability to move objects. Heat, light, and electricity are forms of energy (p. 119)

Eohippus (ē ō hĭp′u̯s). A prehistoric animal somewhat like the modern horse (p. 49)

erosion (ē rō′zhu̯n). The gradual wearing away of the earth's surface; the loosening and carrying away of rock and soil by wind, water, or ice (p. 504)

Eskimo (ĕs′kĭ mō). A people most of whom live on the arctic coasts of America (p. 38)

European corn-borer. A serious insect pest. The moth lays masses of eggs on cornstalks, and the larvae bore into the stems and ears of the corn (p. 79)

exhaust stroke. The fourth and last stroke of the piston in a gasoline engine. It forces the waste gases out of the cylinder (p. 274)

external-combustion engine. An engine in which the pressure producing the motion comes from burning which takes place outside the cylinder (p. 271)

extraction. Separation of metals from their ores (p. 119)

fallow (făl′ō). Land that is left unplanted after plowing (p. 571)

Faraday, Michael (1791–1867). An English chemist and pioneer worker in generating electricity (p. 321)

feldspar (fĕld′spär). The most abundant of all the minerals in the earth's crust (p. 565)

fertilize. To make an egg cell capable of developing into a new organism. For this to be so, a sperm cell must unite with it (p. 25)

fertilized egg. An egg which will develop into a new plant or animal (p. 27)

fertilizer (fûr′tĭ līz ẽr). Any substance which is added to the soil for the purpose of aiding plant growth (p. 41)

filament (fĭl′a̯ mĕnt). A very thin "thread" of a material which conducts electricity (p. 301)

Fitch, John (1743–1798). An American inventor who constructed an early steamboat (p. 369)

flood plain. The part of a river valley which is flooded when the river overflows (p. 567)

flywheel. A comparatively heavy wheel attached to certain mechanisms; it helps to produce smooth motion (p. 162)

foot-pound. A measure of work; the work done when one pound is moved one foot (p. 222) *force.* A push or a pull; that which makes objects move (p. 220)

forceps (fôr'ce̯ps). A pair of pincers or tongs (p. 121)

Forest Service. A bureau of the United States Department of Agriculture (p. 521)

forsythia (fŏr sĭth'ĭ a̯). An early blooming shrub; its yellow flowers appear before the leaves do (p. 22)

four-cycle engine. An engine having a four-stroke cycle—intake, compression, power, and exhaust (p. 273)

foxglove. A plant having dotted white or purple flowers (p. 72)

Frasch (fräsh), *Herman* (1852–1914). An American chemist and inventor (p. 186)

free. Not united with anything else; said of a metal which occurs uncombined (p. 112)

frequency (frē'kwe̯n sĭ). The number of complete cycles taking place in a second (p. 358)

friction (frĭk'shu̯n). The resistance or drag brought about when two substances are rubbed together (p. 226)

fulcrum (fŭl'kru̯m). The support about which a lever turns (p. 228)

Fulton, Robert (1765–1815). American engineer and inventor, who is remembered because he built the first successful steamboat (p. 116)

fungus (fŭn'gu̯s) (plural *fungi* [fŭn'jī]). A plant that has no chlorophyll and produces spores. Fungi live on other plants (p. 71)

galvanized (găl'va̯ nīzd) *iron.* Iron or steel coated with a thin layer of zinc (p. 154)

galvanometer (găl va̯ nŏm'ĕ tẽr). An instrument that shows the presence or direction of a small electric current (p. 324)

gas oil. One of the products of heating crude oil. Gasoline and fuel oil are obtained from gas oil (p. 210)

generate (jĕn'ẽr āt). To produce; for example, steam may be generated in a boiler and may be used in the generation of electricity (p. 176)

generator (jĕn'ẽr ā tẽr). A machine in which mechanical energy is used to produce electric energy (p. 324)

geology (jē ŏl'ō jĭ). The study of the structure and the history of the earth, especially as shown by the rocks (p. 52)

gland. An organ of the body which produces a fluid (p. 420)

glucose (glo͞o'kōs). A simple sugar formed during the digestion of carbohydrates (p. 416)

glycogen (glī'kō jĕn). A carbohydrate found in large amounts in the liver (p. 416)

Gorgas (gôr'ga̯s), *William* (1854–1920). An American sanitation expert, noted for his work in the Panama Canal Zone. He was Surgeon General of the United States Army (p. 463)

grade. An animal having one pure-bred parent; high-grade stock (p. 58)

graduated cylinder. A vessel for measuring liquids (p. 156)

grafting. The insertion of a part of one plant into a part of another, so that the union will become permanent (p. 22)

Grand Coulee (ko͞o'lē) *Dam.* A dam on the Columbia River in Washington, designed for flood control, irrigation, and power production (p. 176)

graphite (grăf'īt). A form of carbon which occurs in nature. It is soft, black, and shiny (p. 149)

grassland. A large area of grass-covered ground (p. 37)

gravity (grăv'ĭ tĭ). The attraction of two objects for each other. For example, there is an attraction between the earth and objects on or near its surface (p. 222)

green manure. Plants which are grown for the purpose of being plowed under in order to fertilize soil (p. 569)

Gregorian (grĕ gō'rĭ a̭n) *calendar.* The calendar now in use. It was introduced in the sixteenth century (p. 400)

guano (gwä'nō). Waste product of birds; it is used as manure (p. 189)

guayule (gwä yo͞o'lā). A shrublike plant of northern Mexico and Texas (p. 17)

Guernsey (gûrn'zĭ). A breed of dairy cattle, usually white and fawn (p. 53)

gully (gŭl'ĭ). A rut deepened and widened by rain and running water (p. 574)

gusher (gŭsh'er). An oil well which is out of control (p. 563)

gypsum (jĭp'sṷm). A mineral (a compound of calcium) which is used for improving soils and for making plaster of Paris (p. 191)

Hard Red Calcutta. A variety of wheat which ripens early (p. 26)

hematite (hĕm'a̭ tīt). The most common iron ore used for the manufacture of iron; it is a compound of iron and oxygen (p. 136)

Hereford (hĕr'ĕ fẽrd). A breed of hardy beef cattle (p. 52)

Holstein (hōl'stīn). A breed of large black-and-white cattle raised for milk production (p. 52)

hookworm. A bloodsucking worm that can live in the intestines of man and some animals; also the disease caused by this worm (p. 453)

hormone (hôr'mōn). A substance produced by a gland of internal secretion (p. 422)

horsepower. A measure of the rate of doing work (p. 40) *humus* (hū'mu̯s). Partly decayed vegetable or animal matter, used as fertilizer (p. 566)

hybrid (hī'brĭd). The offspring of parents of different species, or varieties (p. 25)

hybridization (hī brĭd ī zā'shu̯n). Interbreeding; production of plants or animals whose parents have different traits (p. 26)

hydraulic (hī drô'lĭk) *mining.* Mining that is done by machinery driven by water power (p. 188)

hydrochloric (hī drō klō'rĭk) *acid.* A compound of hydrogen and chlorine dissolved in water (p. 124)

hydroelectric (hī drō ē lĕk'trĭk). Having to do with the production of electric power by the use of water (p. 326)

hydrogen (hī'drō jĕn). A colorless gas, the lightest element known (p. 118)

hydrophobia (hī drō fō'bĭ a̯). An animal disease which may be transmitted to human beings. Hydrophobia, or rabies, is treated by injections of antitoxin (p. 453)

image (ĭm'ĭj). The likeness of an object produced by a lens or a mirror (p. 290)

immune (ĭ mūn'). Able to resist disease (p. 98)

Inca (ĭng'ka̯). An Indian tribe of Peru (p. 13)

incinerator (ĭn sĭn'ẽr ā tẽr). A building or furnace in which garbage may be burned at high temperature (p. 484)

inclined plane. One of the six simple machines; a sloping level surface (p. 229)

incubator (ĭn'kū bā tẽr). An apparatus for keeping eggs at conditions favorable for hatching (p. 56)

inertia (ĭn ûr'sha̯). The property of an object by which it remains at rest or in motion unless some outside force acts upon it (p. 224)

infrared rays. Rays whose wave lengths are longer than those of light but shorter than those of radio waves (p. 284)

inoculate (ĭn ŏk'ū lāt). To make immune to a disease by injecting a serum (p. 98)

insulator (ĭn'sū lā tẽr). A substance that conducts electricity or heat very poorly or not at all (p. 256)

insulin (ĭn'sū lĭn). A secretion of the pancreas; it regulates the use of sugar by the body (p. 422)

intake stroke. The first stroke of the piston on a gasoline engine. It brings fuel into the cylinder (p. 272)

internal-combustion engine. An engine in which the pressure producing motion comes from burning which occurs in the cylinder (p. 270) *invar* (ĭn vär′). An alloy of nickel and iron; it scarcely expands at all at ordinary temperatures (p. 162)

involuntary (ĭn vŏl′ụn tĕr ĭ). Not directed by the will. An action which takes place without thought, such as breathing, is involuntary (p. 413)

iris (ī′rĭs). The colored portion of the eye (p. 294)

Iron Age. A period in human culture, named from the widespread use of iron (p. 106)

Japanese beetle. A small green-and-brown beetle, a serious and destructive pest. The adults feed upon leaves and fruit; the larvae eat grass roots (p. 79)

Jersey. A breed of cattle, rather small in size, whose milk is rich in cream (p. 53)

Julian calendar. The calendar introduced by Julius Caesar, which is almost the same as that in use today (p. 399)

kayak (kī′ăk). An Eskimo canoe, usually made of sealskin (p. 367)

key. A small switch for opening and closing an electric circuit (p. 345)

kilocycle (kĭl′ō sī k′l). One thousand cycles (p. 358)

kilowatt (kĭl′ō wŏt). A measure of electric power; one thousand watts (p. 332)

kilowatt-hour. A kilowatt of electric power used for an hour (p. 332)

kindling temperature. The temperature at which a substance will begin to burn (p. 518)

kinetic (kĭ nĕt′ĭk) *energy.* The energy of any moving object (p. 246)

kitchen midden (mĭd′′n). A refuse heap marking a place where primitive men lived (p. 44).

Kitty Hawk (kĭt′ĭ hôk). The village in North Carolina where the first airplane flight was made in 1903 (p. 383)

Koch, Robert (1843–1910). A very celebrated German physician, who was awarded the Nobel prize in medicine in 1905 (p. 463)

lactic acid. A colorless, sirupy acid, which is present in sour milk (p. 416)

Langley, Samuel P. (1834–1906). An American scientist, who demonstrated that heavier-than-air models could fly (p. 384)

larva (lär′vạ) (plural *larvae* [lär′vē]). The second stage in the life of insects, during which they eat large amounts of food. Larvae are often wormlike, and some are called caterpillars (p. 80)

larynx (lăr′ĭngks). The part of the windpipe in which sounds are produced when the vocal cords vibrate (p. 336) *latitude* (lăt'ĭ tūd). An imaginary line on the earth's surface, parallel to the equator and used to indicate distance north or south of the equator (p. 388)

lead peroxide. A compound of lead and oxygen (p. 152)

Leghorn. A variety of small hardy fowls which are good egg-layers (p. 55)

ligament (lĭg'ȧ me̯nt). A tough band of tissue connecting the ends of bones (p. 408)

lignite (lĭg'nīt). A brownish-black variety of coal, low in carbon content (p. 198)

lines of force. The magnetic field around a magnet or electric wire (p. 322)

Lister, Joseph (1827–1912). An English physician, who revolutionized surgery by introducing an antiseptic system of treatment (p. 463)

litmus paper (lĭt'mu̯s). Paper that is used to show the presence of acids or alkalis (p. 473)

liver fluke (lĭv'ẽr flo͞ok). A flattened worm which infests the livers of cattle, swine, and sheep (p. 96)

llama (lä'ma̯). A South American animal similar to a camel but without a hump (p. 365)

loamy (lōm'ĭ). Consisting of loam; that is, soil containing sand, clay, and humus (p. 12)

locoweed (lō'kō wēd). A weed found in the western part of the United States. It is poisonous to cattle, sheep, and horses (p. 74)

longhorn. A breed of cattle with long horns (p. 61)

longitude (lŏn'jĭ tūd). An imaginary line on the earth's surface connecting the north and south poles and used to indicate the distance east or west of the prime meridian (p. 388)

lucite. A transparent plastic (p. 560)

luminous (lū'mĭ nŭs). Shining by its own light (p. 285)

lunar (lū'nẽr). Having to do with the moon (p. 399)

macadam (ma̯k ăd'a̯m). The road surface constructed by packing a layer of small broken stone on a bed of earth (p. 381)

Machine Age. A period in man's culture which is so called from the widespread use of machines (p. 106)

maggot (măg'u̯t). The larva of a fly, living in decaying matter (p. 482)

magnesium (măg nē'shĭ u̯m). A silver-white, light metal (p. 118)

magnetism (măg'nĕ tĭz'm). The properties of a magnet. The most obvious property of a magnet is its ability to pick up pieces of iron (p. 319) *magnetite* (măg'nĕ tīt). An important iron ore, a compound of iron and oxygen, which sometimes has the properties of a magnet (p. 136)

maize (māz). Corn or Indian corn (p. 9)

malaria (ma̭ lâr'ĭ a̭). A disease caused by microscopic animals in the blood. Malaria is transmitted to man by the bite of one kind of mosquito (p. 18)

mammal (măm'a̭l). Any animal that suckles its young (p. 535)

manganese (măng'ga̭ nēs). A grayish-pink, brittle metal, used in alloys with iron, copper, and silicon (p. 118)

manganese dioxide. A black powder, a compound of oxygen with the metal manganese (p. 152)

mantle (măn't'l). A lacelike cap which glows when placed over a flame (p. 300)

Marconi, Guglielmo (mär kō'nē gōō lyĕl'mō) (1874–1937). An Italian pioneer in wireless telegraphy. He was awarded the Nobel prize in physics in 1909 (p. 356)

marrow (măr'ō). The tissue that fills the cavities of most bones (p. 411)

Maya (mä'ya̭). A South American Indian tribe, which had a high culture when discovered by Europeans (p. 13)

measuring worm. The caterpillar, or larva, of a kind of moth (p. 79)

mechanical advantage. In a machine, the ratio of the resistance to the effort necessary to overcome that resistance (p. 229)

membrane. A thin, flexible layer of material, usually of animal or vegetable origin (p. 74)

Mendel (mĕn'dḙl), *Gregor* (1822–1884). An Austrian monk who investigated the way plants inherit their characteristics (p. 28)

Mendelian (mĕn dē'lĭ a̭n). Referring to Mendel's laws of the inheritance of characteristics (p. 32)

meridian. An imaginary circle or semicircle on the earth's surface, connecting the north and south poles at any place (p. 389)

metallurgy (mĕt''l ûr jĭ). The extraction of metals from their ores (p. 556)

metamorphosis (mĕt a̭ môr'fō sĭs). A change of form, as the change from the pupa stage to the adult stage of many insects (p. 83)

metric (mĕt'rĭk). Relating to measurement (p. 156)

Mexican bean beetle. A spotted ladybird which injures bean plants; a serious pest in the United States (p. 79)

mica (mī'ka̭). A mineral which may readily be separated into very thin, transparent sheets that are more or less elastic. Mica is sometimes called isinglass (p. 191) *microscopic* (mī krō skŏp′ĭk). An object so small that it can be seen only with the aid of a microscope (p. 96)

migratory (mī′gra̤ tō rĭ). Moving habitually from one region to another (p. 543)

millet (mĭl′ĕt). Any of various grains which are often called sorghums in the United States (p. 10)

mineral (mĭn′ẽr ăl). A substance which has a definite chemical composition and is found in the earth's crust (p. 62)

mixture (mĭks′t͜ūr). A substance consisting of two or more other substances in which each keeps its own properties. The composition of a mixture may be different at different times (p. 129)

mold. A fungus or the woolly growth of the fungus (p. 90)

mortar (môr′tẽr). A building material which hardens. It is made by mixing lime, cement, or gypsum with sand and water (p. 170)

mullein (mŭl′ĭn). A weed with coarse woolly leaves and spikes of yellow flowers (p. 70)

narcotic (när kŏt′ĭk). A substance that produces sleep and, in large doses, death (p. 457)

natural gas. A fuel gas obtained from the earth (p. 196)

Neanderthal (nā än′dẽr täl) *man.* One of the earlier races of man that lived in Europe during the third interglacial period, that is, just before the most recent advance of the ice (p. 107)

nerve cell. A cell usually having two branches along which a nerve current may flow (p. 426)

nerve fiber. One of the slender threads or branches of the nerve cell (p. 426)

nervous system. The network of nerves spreading to all parts of the body and connected with the brain (p. 424)

neuron (nū′rŏn). A nerve cell with its branches (p. 430)

Newcomen, Thomas (1663–1729). An English blacksmith, who was one of the inventors of the steam engine (p. 116)

nightshade. Any of a certain family of plants. Many are troublesome weeds, and a few, like the potato, are important food plants (p. 74)

nitrate (nī′trāt). A kind of compound which contains nitrogen and oxygen (p. 76)

nitric (nī′trĭk) *acid.* A compound of hydrogen, nitrogen, and oxygen. It is a very strong acid (p. 143)

nitrogen (nī′trō gḙn). A gaseous element which makes up about four fifths of the air and is present in all living things (p. 68)

Noguchi, Hideyo (1876–1928). A Japanese physician in America whose work on yellow fever was outstanding (p. 463)

nylon. An artificial silk (p. 560)

ohm (ōm). A measure of the resistance of a conductor to the flow of electricity through it (p. 329)

Ohm, Georg (1787–1854). A German electrician (p. 329)

oil shale. Rock from which petroleum may be obtained, although in comparatively small amounts (p. 563)

olfactory (ŏl făk'tō rĭ) *nerve.* The special nerve of smell (p. 429)

opaque (ō pāk'). A substance through which light rays will not pass (p. 286)

open-hearth process. A process of manufacturing steel from pig iron (p. 140)

optic (ŏp'tĭk) *nerve.* The nerve which goes to the brain from the eye (p. 295)

ore. A mineral from which a metal may be profitably extracted (p. 115)

organ (ôr'ga̭n). A part of a plant or an animal which has a particular use (p. 426)

ovary (ō'va̭ rĭ). In plants, the enlarged hollow portion at the base of the pistil in which the seeds develop (p. 27)

ovule (ō'vūl). The egg cell of a plant, which develops into the seed after it has been fertilized by a sperm cell (p. 27)

oxide (ŏk'sīd). A compound of oxygen with one other element (p. 147)

oxygen (ôk'sĭ jḙn). A colorless gas, the most abundant of all the elements (p. 118)

Palomar, Mount. A mountain in California, where the largest telescope is being set up (p. 184)

pancreas (păn'krē ăs). A large gland located just below the stomach. It produces a fluid which helps to dissolve foods (p. 421)

parasite (păr'a̭ sīt). A plant or animal which obtains its food or shelter at the expense of another living thing (p. 90)

parathyroid (păr a̭ thī'roid). A small gland near the thyroid gland; the fluid that it secretes is extremely important in regulating the calcium content of the body (p. 421)

passenger pigeon. A North American wild pigeon which once was very abundant but is now extinct (p. 538)

Pasteur (päs tûr'), *Louis* (1822–1895). A famous French chemist (p. 97)

pasteurization (păs tẽr ĭ zā'shṷn). Destruction of dangerous bacteria in milk and other liquids by heating to about 145° F. for thirty minutes (p. 475)

peat (pēt) *moss.* A kind of moss which grows in swamps (p. 22)

pedigree (pĕd'ĭ grē). A list of ancestors (p. 57)

Pekinese (pē kĭn ēz'). A very small, long-haired dog (p. 46)

Percheron (pûr'chẽ rŏn). A draft horse, usually dapple-gray or black, much used in America (p. 50)

percussion (pẽr kŭsh'ṷn). Striking (p. 362)

phosphate (fŏs'fāt). A kind of compound which contains both phosphorus and oxygen (p. 62)

phosphorus (fŏs'fō rṷs). An element which burns at a very low temperature (p. 118)

physics (fĭz'ĭks). The science of matter and motion (p. 287)

pig iron. Iron as it comes from the blast furnace (p. 140)

pigweed. A common weed, sometimes called goosefoot (p. 19)

pistil (pĭs'tĭl). An organ in the center of the flower; it receives the pollen and later contains the developing seeds (p. 27)

piston (pĭs'tṷn). A sliding piece inside the cylinder of an engine or pump; it moves when it is pushed by gas or liquid (p. 116)

piston rod. A rod attached to the piston of an engine by which the piston's motion is transferred (p. 266)

pitch. The property of sound determined by the number of vibrations that strike the ear per second (p. 330)

pith. The substance inside the stem of a plant (p. 309)

pituitary (pĭ tū'ĭ tẽr ĭ). A small gland in the brain (p. 421)

plague (plāg). An epidemic disease occurring in several forms, one of which is bubonic plague (p. 448)

plantain (plăn'tĭn). A common weed with large spreading leaves close to the ground (p. 70)

plasma (plăz'ma̭). The liquid part of the blood (p. 419)

plaster of Paris. A white, powdery calcium compound which forms a quickly setting paste with water (p. 191)

plastic (plăs'tĭk). An artificial resin. There are many plastics and many uses for them (p. 558)

platinum (plăt'ĭ nṷm). A silver-gray metal used in certain chemical reactions and for some jewelry (p. 161)

Plymouth Rock. An American breed of medium-sized domestic fowl (p. 55)

pokeweed. A coarse weed whose berries and roots are poisonous. It was used as a dye by the Indians (p. 74)

pollen (pŏl'ḙn). The fine yellow "dust" produced by flowers. It is necessary in the formation of seeds (p. 27)

pollination (pŏl ĭ nā'shṷn). The transfer of pollen from the stigma to the pistil (p. 27)

Polynesian (pŏl ĭ nē'sha̭n). One of a group of people living throughout Oceania, that is, in the Pacific islands (p. 366)

potash (pŏt'ăsh). Potassium carbonate, a compound of potassium, carbon, and oxygen (p. 76) *potassium* (pō tăs′ĭ u̯m). A soft, white metal which has many important compounds (p. 118)

potential (pō tĕn′sha̯l) *energy.* Energy which is stored or inactive, but which can become active (p. 246)

power. Rate of doing work (p. 330)

power stroke. The third stroke of the piston in a gasoline engine. It is caused by the explosion of the fuel (p. 272)

Pribilof (prē bē lŏf′) *Island.* Fur-seal breeding grounds in the Bering Sea, near Alaska (p. 540)

primary production. Metals produced directly from ore (p. 558)

prime meridian. The meridian from which longitude is counted, both east and west (p. 389)

prism (prĭz′m). A transparent object which causes light rays to be refracted in a regular manner (p. 279)

proportion (prō pōr′shu̯n). The relation of one part to another, or the relation of a part to the whole (p. 29)

protein (prō′tē ĭn). A complex substance which always contains nitrogen and which is a part of all living things. Some foods are especially rich in proteins (p. 62)

proton (prō′tŏn). A particle of positive electricity (p. 312)

protozoan (prō tō zō′a̯n). A one-celled animal, too small to be seen with the naked eye (p. 445)

pulsating current. An electric current which varies in strength (p. 350)

pulsation (pŭl sā′shu̯n). A rhythmical throbbing or vibrating (p. 358)

pupa (pū′pa̯) (plural *pupae* [pū′pē]). The third stage in the life of some insects, during which they are very inactive. Cocoons contain and protect pupae (p. 81)

pure-bred. Of a recognized breed kept pure for many generations (p. 58)

pusley (pŭs′lĭ). A common plant sometimes used for salad or for flavoring (p. 19)

pyralin (pī′ra̯ lĭn). An artificial substance resembling ivory (p. 559)

quality (kwŏl′ĭ tĭ). The property of a sound which distinguishes it from another having the same pitch and loudness (p. 340)

quartz (kwôrts). A hard, abundant mineral which is a form of silica. It may be colorless or colored; when pure, it is transparent (p. 185)

queen. The fully developed female bee which produces the eggs (p. 59)

Queen Anne's lace. The wild carrot (p. 71)

quicklime (kwĭk′līm). Calcium oxide (p. 173)

quinine (kwī′nīn). A drug obtained from the bark of the cinchona tree; it is useful in the treatment of malaria (p. 18)

radiant (rā′dĭ a̯nt) *energy*. A form of energy which travels in straight lines, or rays, through empty space. When these rays strike a substance, the energy is absorbed and is changed to heat energy (p. 250)
radiation (rā dĭ ā′shu̯n). The process by which energy is sent through space (p. 254)
radiometer (rā dĭ ŏm′ĕ tẽr). An instrument which demonstrates the energy of the sun's rays (p. 250)
radium (rā′dĭ u̯m). An element which gives off radiant energy (p. 25)
ragweed. A weed whose pollen is one cause of hay fever (p. 74)
rain forest. The type of plant life found where rain is abundant and the temperature is high (p. 33)
rayon (rā′ŏn). An artificial silk made from cellulose (p. 524)
react (rē ăkt′). To take part in a chemical change (p. 124)
receptor (rē sĕp′tẽr). A sense organ which is able to receive and pass on stimuli, such as light and sound (p. 426)
recessive (rē sĕs′ĭv). A characteristic that does not appear in the first generation of hybrids (p. 30)
Red Fife. A variety of wheat which bears abundantly (p. 26)
reflex (rē′flĕks) *action*. A simple action or movement of the body brought about when a nerve impulse is transmitted from a sense organ through the spinal cord to an organ or member which acts (p. 432)
refraction (rē frăk′shu̯n). The bending of a ray of light as it passes from one transparent substance into another (p. 287)
reproduce (rē prō dūs′). To produce offspring or young (p. 27)
retina (rĕt′ĭ na̯). The sensitive membrane at the back of the eye; it receives the image formed by the lens and is connected with the brain by the optic nerve (p. 294)
Rhode Island Red. An important American breed of domestic fowl, valued both for eggs and for meat (p. 55)
rods and cones. The small receptor organs for vision located in the retina (p. 427)
rookery (ro͝ok′ẽr ĭ). Breeding grounds used by seals, rooks, herons, and the like (p. 542)
rotary (rō′ta̯ rĭ) *oil rig*. An apparatus used in drilling oil wells (p. 207)
rotary table. A platform turned by an engine, used in drilling for oil (p. 207)
rust. A fungus plant, resembling iron rust in appearance (p. 90)

saprophyte (săp′rō fīt). A plant which secures its food from the dead body of another plant or animal (p. 90)
scrub. A domestic animal of mixed or unknown parentage (p. 58)
secondary production. Metals produced from scrap (p. 558)

secretion (sē krē'shṷn). A liquid prepared in a gland and usually serving a special purpose in the body (p. 420)

sediment (sĕd'ĭ mḙnt). Solid particles which settle out of water (p. 206)

sedimentation (sĕd ĭ mĕn tā'shṷn) *tank.* A tank in which the solid part of sewage is allowed to settle (p. 486)

self-pollination. The transfer of pollen from the stamen of a flower to the pistil of the same flower (p. 27)

sense organ. A part of the body which responds to a certain kind of stimulation (p. 426)

sensory (sĕn'sō rĭ) *neuron.* A neuron which carries an impulse from a sense organ (p. 430)

septic (sĕp'tĭk) *tank.* A tank in which sewage may be changed into liquid matter and gases by the action of bacteria (p. 485)

shad. A food fish of the North Atlantic coast (p. 535)

Shorthorn. A breed of black-and-white beef cattle (p. 53)

Shropshire (shrŏp'shĭr). An English breed of hornless, black-faced sheep, which produce superior mutton (p. 48)

sidereal (sī dēr'ē a̭l). Measured by the apparent motion of the stars (p. 398)

silica (sĭl'ĭ ka̭). A compound containing oxygen and the element silicon. The sand of the seashore is a variety of silica (p. 138)

silicon (sĭl'ĭ ko̭n). An element which always occurs in combined form and which is, next to oxygen, the most abundant element in the earth's crust (p. 118)

skeletal muscle (skĕl'ĕ ta̭l mŭs''l). A muscle attached to the skeleton (p. 413)

slag. Cinderlike material produced during the smelting of iron (p. 139)

slaked lime. Quicklime which has been caused to give out heat and to crumble by treatment with water (p. 173)

slide valve. A sliding valve which allows steam to enter and leave the cylinder of a steam engine (p. 266)

slip. A cutting from a plant (p. 22)

slipping. The process of planting slips (p. 22)

sodium (sō'dĭ ṷm). A soft, silver-white metal whose compounds are very abundant (p. 118)

sodium carbonate (kär'bŏn āt). A compound of sodium, carbon, and oxygen; washing soda (p. 177)

sodium chloride. A compound of sodium and chlorine; the chemical name for common salt (p. 120)

sodium hydroxide (hī drŏk'sīd). Caustic soda, a compound of sodium, hydrogen, and oxygen. It is strongly alkaline (p. 122)

Soil Conservation Service. A division of the United States Department of Agriculture (p. 534)

solar (sō'lẽr). Having to do with the sun (p. 251)

soluble (sŏl'ū b'l). Able to dissolve. Sugar is soluble in water (p. 188)

sorghum (sôr'gṷm). Any one of about thirty-five kinds of grass (p. 572)

sorrel (sŏr'ḙl). A plant with sour-tasting leaves (p. 72)

sounder (sound'ẽr). An electromagnet with an armature placed above it, used for sending telegraph messages (p. 345)

spawning (spôn'ĭng). The producing of eggs by fishes (p. 544)

species (spē'shĭz). A group of plants or animals having certain traits in common (p. 539)

spectroscope (spĕk'trō skōp). An instrument used to determine the elements of which things are made. The spectroscope is used in studying the composition of the heavenly bodies (p. 280)

spectrum (spĕk'trṷm) (plural *spectra*). A band of color produced from white or other complex light by passing light through a prism (p. 280)

sperm (spûrm). A kind of cell which fertilizes an egg cell, so that a new organism may be produced (p. 25)

spinal cord. The cord of nervous tissue which extends along the back (p. 425)

spleen (splēn). A large organ in the body which stores blood for use when needed (p. 435)

spore (spōr). A single cell produced by some plants. Although it is not formed by the union of two cells, as a seed is, it is able to develop into a new plant. Ferns and mushrooms are examples of plants which produce spores (p. 89)

sport. An individual which differs from its parents very much more than would be expected (p. 24)

stamen (stā'mḙn). An organ near the center of the flower; it produces the pollen (p. 27)

standard time. The time established by law or usage over certain sections (p. 394)

static (stăt'ĭk) *electricity.* A form of electricity in which electrons are stored on a nonconductor, as contrasted with current electricity in which electrons flow along a conductor (p. 311)

steam chest. The part of a steam engine into which steam enters before going into the cylinder (p. 266)

Stephenson, George (1781–1848). An English engineer who pioneered in building steam locomotives (p. 116)

stigma (stĭg'ma̭). The sticky end of the pistil, on which pollen is deposited (p. 27)

stimulus (stĭm′ū lṷs). Anything that causes a response (p. 431)
Stone Age. The first known period of human culture, when men made stone tools. The Stone Age is divided into two parts: the Old Stone Age, which is called the Paleolithic, and the New Stone Age, called the Neolithic (p. 104)
stratoliner. A transport airplane built for use above the clouds (p. 386)
striated (strī′āt ĕd). Marked with narrow bands or stripes (p. 413)
strip-cropping. Planting strips of crops which give minerals to the soil next to strips of crops which take minerals from it (p. 575)
sturgeon (stûr′jṷn). A large food fish whose eggs are made into caviar (p. 535)
submarginal (sŭb mär′jĭ na̭l) *land.* Land which is too poor to be profitably farmed (p. 517)
sulfide (sŭl′fīd). A compound of sulfur usually with a metal or with hydrogen (p. 147)
sulfur (sŭl′fẽr). A yellow, nonmetallic element (p. 118)
sulfuric (sŭl fū′rĭk) *acid.* A compound of hydrogen, sulfur, and oxygen, which is very important in industry (p. 76)

tactile (tăk′tĭl). Having to do with the sense of touch (p. 426)
tarsier (tär′sĭ ẽr). An East Indian animal that lives in trees and goes about at night (p. 297)
taste buds. Sense organs on the tongue which contain the receptors for taste (p. 429)
teak (tēk). A tall East Indian tree. Its hard, yellowish-brown wood is used especially for shipbuilding (p. 43)
technical (tĕk′nĭ ka̭l). Highly specialized; used only in a particular subject or profession (p. 22)
teletype (tĕl′ē tīp). A form of printing telegraph, whose use makes it possible for a message to be typed at both ends of the telegraph circuit at the same time (p. 346)
television (tĕl′ĕ vĭzh ṷn). A means of broadcasting and receiving scenes in which light rays are converted into very short radio waves which are then turned back into light rays (p. 359)
terrace. Crops planted on different levels in order to lessen erosion (p. 575)
tetanus (tĕt′a̭ nŭs). A disease caused by a toxin. In tetanus the muscles become rigid (p. 448)
thermostat (thûr′mō stăt). A device which regulates the temperature, usually by controlling the air supply of a furnace (p. 262)
thorium (thō′rĭ ṷm). A comparatively rare metallic element which gives off radiant energy (p. 132)

thymus (thī'mu̯s). A gland in the neck which is active in childhood (p. 421)
thyroid (thī'roid) *gland.* A large gland in the neck, near the larynx (p. 421)
tin plate. Thin sheet iron or steel coated with tin (p. 160)
tissue (tĭsh'ū). The material of which body organs are composed. Tissues are made up of cells (p. 410)
titanium (tī tā'nĭ u̯m). An element somewhat like silicon (p. 118)
Titicaca (tē tē kä'kä), *Lake.* The highest navigable lake in the world; its altitude is 12,644 feet (p. 366)
topsoil. The surface soil (p. 62)
toxin (tŏk'sĭn). A poison produced by certain bacteria (p. 449)
toxin-antitoxin. A mixture of toxin with antitoxin. There is less danger in injecting toxin-antitoxin than antitoxin alone (p. 451)
trichinosis (trĭk ĭ nō'sĭs). A disease of the intestines caused by a parasite (p. 469)
Trudeau (tro͞o'dō), *Edward* (1848–1915). An American physician, noted for his work on tuberculosis (p. 463)
tuber (tū'bẽr). A thickened part of a stem, usually underground, bearing what we call "eyes." White potatoes are tubers (p. 15)
tungsten (tŭng'ste̯n). A metal with a very high melting point (p. 132)
turbine (tûr'bĭn). A machine in which running water or steam is used to produce electricity (p. 268)
typhoid (tī'foid) *fever.* A disease caused by bacteria taken into the body in food or drinking water (p. 445)

ultraviolet rays. A form of radiant energy given off by the sun. These rays are invisible and help to maintain health (p. 185)
universe. An enormous group of stars. What we call our sun is a star in one such group (p. 117)
uranium (ū rā'nĭ u̯m). A heavy metallic element which gives off radiant energy (p. 132)

vacuum (văk'ū u̯m). A space which contains no matter (p. 272)
valve (vălv). An opening in a tube or container which allows gases or liquids to pass (p. 208)
vanadium (va̯ nā'dĭ u̯m). A rare, light-gray metal used to alloy with steel (p. 132)
vein (vān). Any of the blood vessels which carry blood to the heart (p. 419)
ventricle (vĕn'trĭ k'l). One of the two lower chambers of the heart (p. 419)

vibration (vī brā'shu̯n). Rapid back-and-forth motion (p. 163)

virgin forests. Forests that have not been cut (p. 514)

Virginia creeper. A common North American vine with bluish-black berries (p. 73)

vitamin (vī'ta̭ mĭn). A compound which we must take into our bodies, if we wish to remain healthy (p. 410)

volt (vōlt). A measure of the pressure which forces electricity through a substance (p. 330)

Volta (vôl'tä), *Alessandro* (1745–1827). An Italian scientist who studied electricity and made the first electric cell (p. 318)

voluntary (vŏl'u̯n tĕr ĭ). Regulated or directed by the will (p. 413)

water gas. A gas made by forcing steam over hot glowing coke (p. 203)

water hemlock. A poisonous herb (p. 74)

water hyacinth. A tropical floating plant with large blue flowers (p. 72)

Watt, James (1736–1819). Scottish inventor of the steam engine in 1769 (p. 116)

watt. A measure of electric power (p. 330)

watt-hour. The work done when one watt is used for one hour (p. 331)

wave length. The distance from a point in one wave to the corresponding point in the next wave (p. 280)

weight. The amount of pull exerted upon an object by the force of gravity (p. 221)

Welsbach (wĕlz băk) *burner.* A gas mantle which glows when a mixture of air and gas is burned (p. 300)

whippet (hwĭp'ĕt). A small, swift dog developed from a cross between a greyhound and a terrier (p. 46)

white-pine blister rust. A disease of white pines, caused by a fungus (p. 92)

Wiley, Harvey W. (1844–1930). An American physician, recognized in the United States and Europe as an authority on pure food (p. 490)

Wilson, Alexander (1766–1813). A Scottish naturalist living in America, who studied bird life (p. 539)

work. Work is done whenever an object is moved (p. 220)

wormwood (wûrm'wo͝od). A bitter-tasting herb. The dwarf ragweed is often called wormwood in local usage, although the real wormwood does not belong to the ragweed family (p. 74)

Wright, Orville (1871–   ). An American inventor who, with his brother, built the first successful full-sized, heavier-than-air machine (p. 383)

Wright, Wilbur (1867–1912). An American inventor and aviator, brother of Orville Wright (p. 383)
Wyandotte (wī′a̭n dŏt). A variety of medium-sized fowl (p. 54)

X ray. A form of radiant energy with a very short wave length (p. 25)

yak (yăk). A kind of ox native to Asia (p. 365)

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